BMT Fleet Technology Limited

TP 14498E

Friction Coefficients for Various Winter Surfaces

Prepared for
Transportation Development Centre
On behalf of
Aerodrome Safety Branch of Civil Aviation
Transport Canada

October 2004

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Un sommaire français se trouve avant la table des matières.

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Transport Canada Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.
TP 14498E

2. Project No.
5481

3. Recipient's Catalogue No.

4. Title and Subtitle
Friction Coefficients for Various Winter Surfaces

5. Publication Date
October 2004

6. Performing Organization Document No.

7. Author(s)
G. Comfort and A. Mazur

8. Transport Canada File No.
2450-BP14

9. Performing Organization Name and Address
BMT Fleet Technology Limited
311 Legget Drive
Kanata, Ontario
Canada K2K 1Z8

10. PWGSC File No.
MTB-3-01087

11. PWGSC or Transport Canada Contract No.
T8200-033527/001/MTB

12. Sponsoring Agency Name and Address
Transportation Development Centre (TDC)
800 René Lévesque Blvd. West
Suite 600
Montreal, Quebec
H3B 1X9

13. Type of Publication and Period Covered
Final

14. Project Officer
A. Boccanfuso

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

A large set of field data has been obtained over the past eight years, as part of the Joint Winter Runway Friction Measurement Program (JWRFMP), to define Canadian Runway Friction Indexes (CRFIs) on winter surfaces. The field data from the JWRFMP have been analyzed to update Table 4 of the Aeronautical Information Publication (AIP), which contains representative values for CRFIs on various surfaces.

The JWRFMP data were also used to investigate the effect of surface conditions on CRFIs for: (a) decelerometers; (b) the TC SFT'79, and (c) the combination of the IRV and the IMAG (both force and torque measurements).

17. Key Words
Runway, friction, field data, Joint Winter Runway Friction Measurement Program, JWRFMP, friction coefficient

18. Distribution Statement
Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)
Unclassified

20. Security Classification (of this page)
Unclassified

21. Declassification (date)
—

22. No. of Pages
xviii, 28, apps

23. Price
Shipping/ Handling

Transports Canada Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. Nº de la publication de Transports Canada
TP 14498E

2. Nº de l'étude
5481

3. Nº de catalogue du destinataire

4. Titre et sous-titre
Friction Coefficients for Various Winter Surfaces

5. Date de la publication
Octobre 2004

6. Nº de document de l'organisme exécutant

7. Auteur(s)
G. Comfort et A. Mazur

8. Nº de dossier - Transports Canada
2450-BP14

9. Nom et adresse de l'organisme exécutant
BMT Fleet Technology Limited
311 Legget Drive
Kanata, Ontario
Canada K2K 1Z8

10. Nº de dossier - TPSGC
MTB-3-01087

11. Nº de contrat - TPSGC ou Transports Canada
T8200-033527/001/MTB

12. Nom et adresse de l'organisme parrain
Centre de développement des transports (CDT)
800, boul. René-Lévesque Ouest
Bureau 600
Montréal (Québec)
H3B 1X9

13. Genre de publication et période visée
Final

14. Agent de projet
A. Boccanfuso

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

16. Résumé

Une somme colossale de données de terrain a été accumulée ces huit dernières années dans le cadre du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH), afin de définir les coefficients canadiens de frottement sur piste (CRFI, pour *Canadian Runway Friction Index*) sur des surfaces hivernales. Ces données ont été analysées et ont servi à mettre à jour le tableau 4 de la publication d'information aéronautique (AIP, pour *Aeronautical Information Publication*), qui contient des valeurs représentatives du CRFI sur diverses surfaces.

Les données recueillies par le PCRGCAH ont aussi été utilisées pour examiner l'effet de l'état de la surface sur le CRFI selon l'appareil de mesure utilisé, soit : a) des décéléromètres; b) le SFT 79 de TC et c) l'IRV et l'IMAG combinés (relevés de la force et du couple).

17. Mots clés

Chaussée, piste, frottement, données de terrain, Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver, PCRGCAH, coefficient de frottement

18. Diffusion
Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)
Non classifiée

20. Classification de sécurité (de cette page)
Non classifiée

21. Déclassification (date)
—

22. Nombre de pages
xviii, 28, ann.

23. Prix
Port et manutention

Canada

ACKNOWLEDGEMENTS

Angelo Boccanfuso, of Transport Canada's Transportation Development Centre, was the project officer.

Dominic Morra, of Transport Canada's Civil Aviation Directorate, provided technical direction.

EXECUTIVE SUMMARY

A large set of field data has been obtained over the past eight years as part of the Joint Winter Runway Friction Measurement Program (JWRFMP) to define Canadian Runway Friction Indexes (CRFIs) on winter surfaces. The Aeronautical Information Publication (AIP) currently contains representative values for CRFIs on various surfaces, although it does not make use of the data collected as part of the JWRFMP.

In this project, the field data from the JWRFMP were analyzed to:

(a) produce material useful for updating Table 4 of the present AIP. The suggested insert for the AIP is shown in Figure 1. It should be noted that the information presented in Figure 1 is applicable to the case where CRFIs are measured with decelerometers.

(b) investigate the effect of surface conditions on CRFIs – this has been done for the following devices:
   a. decelerometers
   b. TC SFT'79
   c. combination of the IRV and the IMAG (both Force & Torque measurements)

Figure 2 compares the CRFIs measured by these devices for some of the surfaces identified for inclusion in the AIP update (Figure 1).

The CRFI depends on the surface type as shown in Table 4a. It should be noted that:

(a) the CRFI values given in Table 4a are applicable to all temperatures. Extensive measurements have shown that the CRFI is not correlated with the surface temperature. The case where the surface temperature is just at the melting point (i.e., about 0°C) may be an exception as a water film may form by surface melting, which could induce slippery conditions with CRFIs less than those in Table 4a.

(b) the CRFI may span a range of values for various reasons, such as variations in texture among surfaces within a given surface class. The expected maximum and minimum CRFIs for various surfaces are listed in Table 4b. Note that these values are based on a combination of analyses of extensive measurements and sound engineering judgment.

(c) the largest range in CRFI is to be expected for a thin layer (3 mm or less in thickness) of loose snow on pavement (Table 4a). This variation may occur due to: (i) non-uniform snow coverage, and/or (ii) the tires breaking through the thin layer. In either case, the surface presented to the aircraft may range from snow to pavement.

Table 4a **Expected Range of CRFI's by Surface Type**

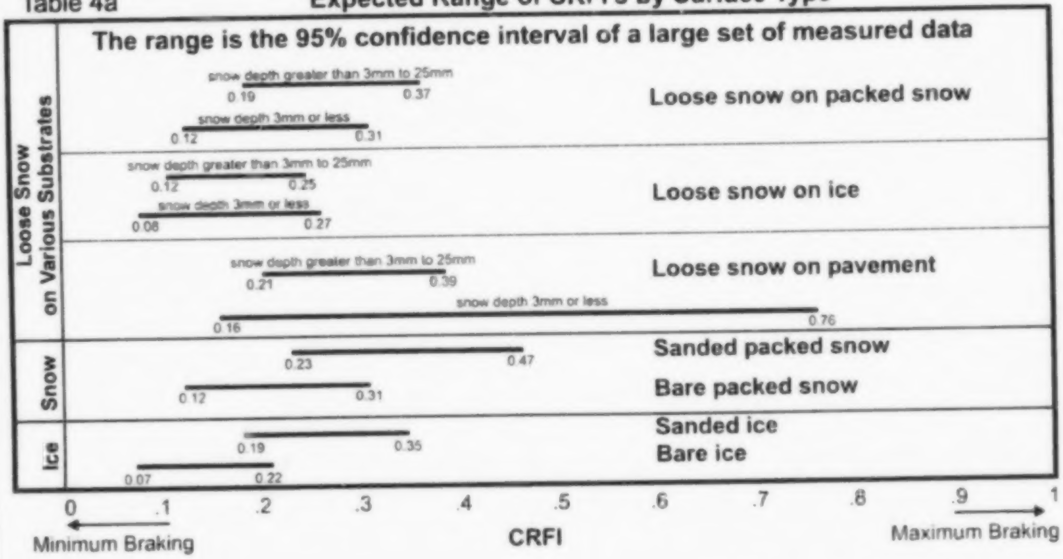

Table 4b **Expected Minimum and Maximum CRFIs for Various Surfaces**

Surface	Lower CRFI Limit	Upper CRFI Limit
Bare Ice	No Limit	0.3
Bare Packed Snow	0.1	0.4
Sanded Ice	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Ice: Depth - 3mm or Less	No Limit	0.4
Loose Snow on Ice: Depth - 3 to 25 mm	No Limit	0.4
Loose Snow on Packed Snow: Depth - 3mm or Less	0.1	0.4
Loose Snow on Packed Snow: Depth - 3 to 25 mm	0.1	0.4

Figure 1: Suggested Insert for the AIP

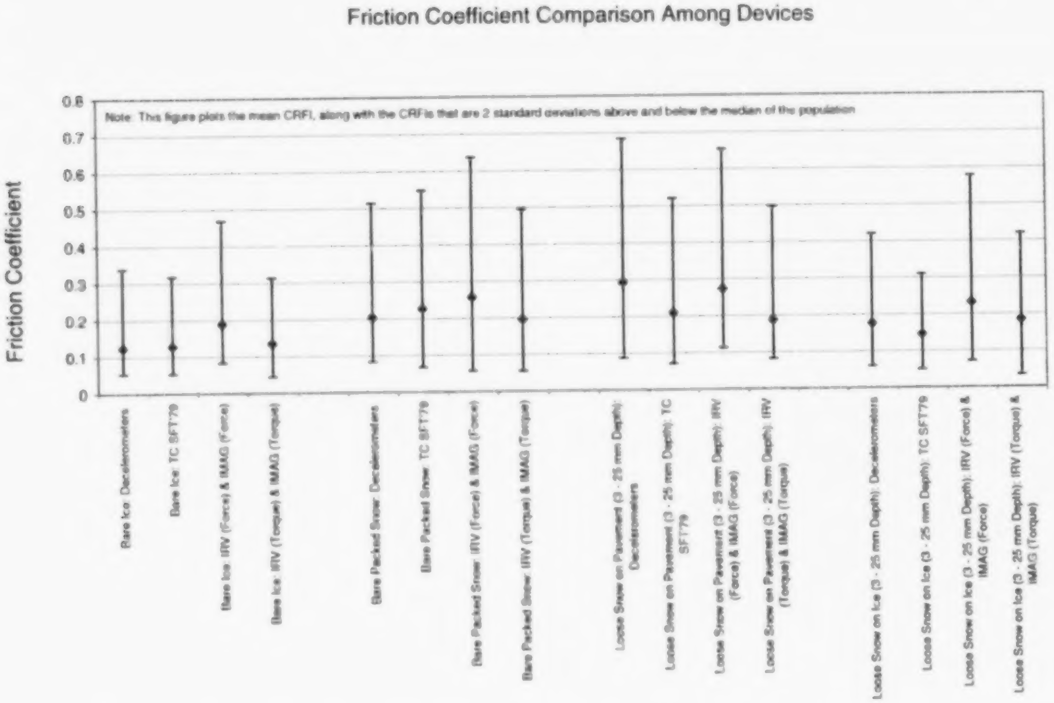

Figure 2: Friction Coefficient Comparison Among Devices

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Une somme colossale de données de terrain a été accumulée ces huit dernières années dans le cadre du Programme conjoint de recherche sur la glissance des chaussées aéronautiques l'hiver (PCRGCAH), afin de définir les coefficients canadiens de frottement sur piste (CRFI) sur des surfaces hivernales. La publication d'information aéronautique (AIP) contient des valeurs représentatives du CRFI sur diverses surfaces, mais ces coefficients ne tiennent pas compte des données recueillies par le PCRGCAH.

Le présent projet a consisté à analyser les données de terrain du PCRGCAH dans le but de :

(a) produire une information utile pour la mise à jour du tableau 4 de l'AIP. L'ajout proposé pour l'AIP est reproduit à la figure 1. Il convient de noter que l'information de la figure 1 découle de relevés faits avec des décéléromètres.

(b) examiner l'effet de l'état de la surface sur le CRFI – cela a été fait pour les dispositifs suivants :
   a. décéléromètres
   b. SFT 79 de TC
   c. IRV et IMAG combinés (relevés de la force et du couple)

La figure 2 compare les CRFI mesurés par ces appareils de mesure sur certaines des surfaces retenues pour la mise à jour de l'AIP (figure 1).

Le CRFI est fonction du type de surface, comme le montre le tableau 4a. Il convient de noter que :

(a) les valeurs CRFI données au tableau 4a s'appliquent à toutes les températures. Un grand nombre de relevés ont révélé l'absence de corrélation entre le CRFI et la température de la surface. La seule exception est peut-être celle d'une température de surface tout juste au point de fusion (près de 0°C), alors qu'une pellicule d'eau résultant de la fusion en surface risque de se former, situation qui peut se traduire par des conditions glissantes donnant des CRFI inférieurs aux valeurs indiquées au tableau 4a;

(b) le CRFI peut varier dans une certaine plage et ce, pour diverses raisons, comme des variations dans la texture des surfaces appartenant à une même catégorie. Les CRFI maximaux et minimaux que devraient avoir les diverses surfaces sont indiqués au tableau 4b. À noter que ces coefficients se fondent sur des analyses d'un grand nombre de relevés combinés à un jugement professionnel éclairé;

(c) la plage la plus importante que peut occuper le CRFI devrait se retrouver en présence d'une mince couche (3 mm ou moins d'épaisseur) de neige folle sur le revêtement (tableau 4a). Cette variation peut s'expliquer comme suit : (i) une couverture neigeuse non uniforme et/ou (ii) le freinage des pneus à travers la fine couche de neige. Dans les deux cas, la surface sur laquelle va rouler l'avion peut aussi bien être de la neige que le revêtement de la piste.

Tableau 4a Plage probable des CRFI en fonction du type de surface

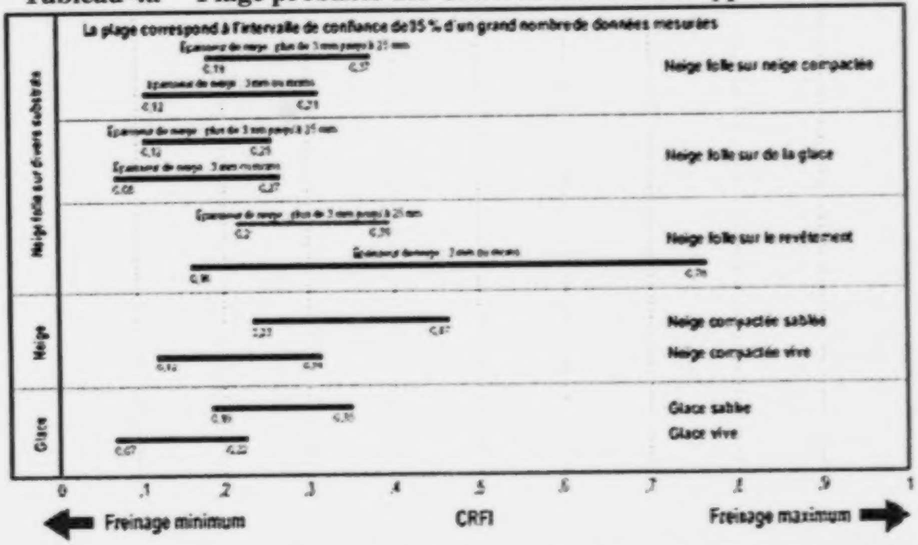
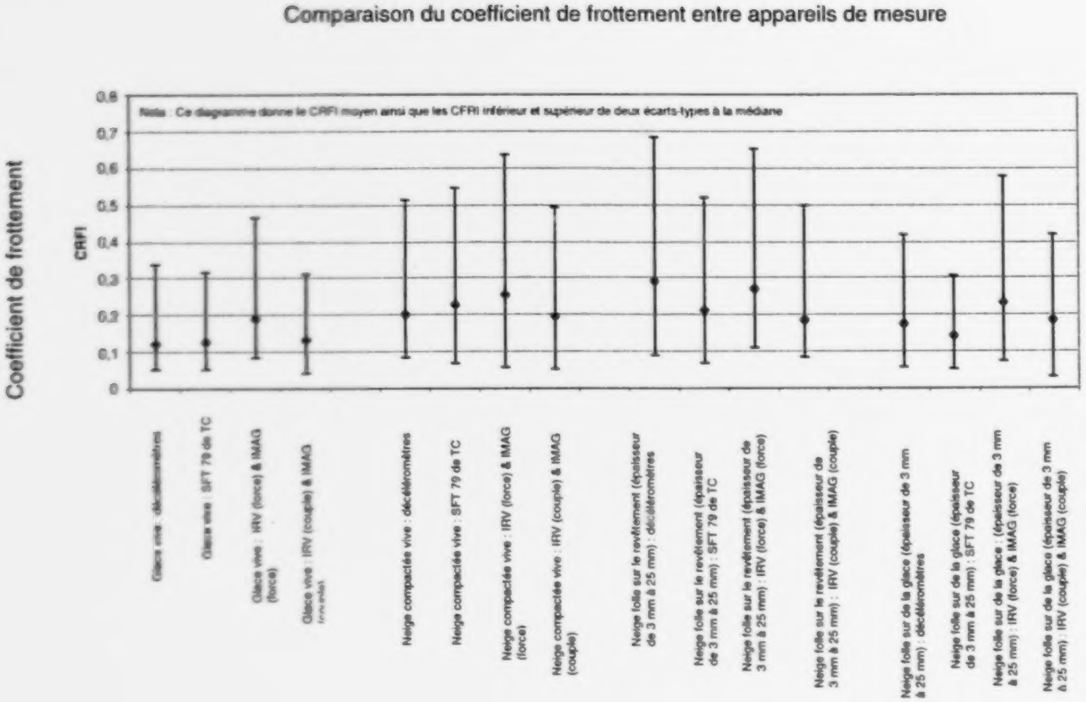


Tableau 4b CRFI minimal et maximal probables pour diverses surfaces

Surface	Limite inférieure du CRFI	Limite supérieure du CRFI
Glace vive	Pas de limite	0,3
Neige compactée vive	0,1	0,4
Glace sablée	0,1	0,4
Neige compactée sablée	0,1	0,5
Neige folle sur de la glace (épaisseur de 3 mm ou moins)	Pas de limite	0,4
Neige folle sur de la glace (épaisseur de 3 mm à 25 mm)	Pas de limite	0,4
Neige folle sur de la neige compactée (épaisseur de 3 mm ou moins)	0,1	0,4
Neige folle sur de la neige compactée (épaisseur de 3 mm à 25 mm)	0,1	0,4
Neige folle sur le revêtement (épaisseur de 3 mm ou moins)	0,1	Revêtement sec

Figure 1: Proposition d'ajout pour l'AIP



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GLOSSARY OF ACRONYMS

ABS	Antilock Braking System
AIP	Aeronautical Information Publication
ASTM	American Society for Testing and Materials
CRFI	Canadian Runway Friction Index
ERD	Electronic Recording Decelerometer
IMAG	Instrument de Mesure Automatique de la Glissance (French acronym for friction-measuring device manufactured by the French Civil Aviation Authority)
IRV	IRFI Reference Vehicle
IRFI	International Runway Friction Index
JWRFMP	Joint Winter Runway Friction Measurement Program
LD	Landing Distance
PIARC	Acronym for World Road Association
TC SFT'79	Surface Friction Tester device owned by Transport Canada
TC	Transport Canada

1. INTRODUCTION

1.1 Background

Testing has been underway in North Bay, Ontario, and elsewhere since 1996 as part of the Joint Winter Runway Friction Measurement Program (JWRFMP) to:

(a) compare the friction readings from various devices; and
(b) evaluate the relationship between ground vehicle and aircraft friction coefficients.

This has generated a large database [1] of information regarding friction coefficients on winter surfaces. Recently, the JWRFMP data were used to investigate the effect of surface conditions on friction coefficients [2].

As well, other test programs, done in 2002 and 2003, have produced a considerable amount of data to define Canadian Runway Friction Indexes (CRFIs) on various winter surfaces at airports ([3] and [4], respectively).

These initiatives have produced a large quantity of data to define friction coefficients on winter surfaces at airports, in relation to the surface condition.

The Aeronautical Information Publication (AIP) [5] currently contains representative values for CRFIs on various surfaces, although it does not make use of the newly collected data.

1.2 Objectives

The objectives of this project were twofold:

(a) to produce material useful for updating the CRFI information in the AIP. These analyses were limited to data collected using decelerometers, as the Landing Distance (LD) tables in the AIP are based on CRFIs measured by decelerometers.

(b) to use the available data to investigate the effect of surface conditions on friction coefficients. These analyses were conducted using data from three general types of devices:

1. decelerometers;
2. the Saab Surface Friction Tester (SFT); and
3. the IRFI Reference Vehicle (IRV), and the Instrument de Mesure Automatique de la Glissance (IMAG).

2. DATA SOURCES AND METHODS

The project was done with considerable input from Transport Canada. For completeness, several of the communications produced are copied in Appendix C.

2.1 Friction-Measuring Devices Selected for Analysis

The following friction-measuring devices were included in the analyses:

(a) decelerometers – decelerometers were included because the LD tables in the AIP are based on CRFIs measured with decelerometers. The vast majority of these data were obtained using the Electronic Recording Decelerometer (ERD) although a few data points obtained with the Bowmonk and Tapley decelerometers were also included. The ERD data included results obtained with both the Mk II and Mk III devices.

(b) Saab Surface Friction Tester (SFT) – data collected with the TC SFT'79 were analyzed. This device was extensively used during the Joint Winter Runway Friction Measurement Program (JWRFMP). Although the TC SFT'79 was tested in a number of configurations [1], [2], only the Configuration 3 data (Table 2.1) were included in the analyses conducted here.

(c) IMAG and IRV – These data were analyzed in two groups as follows:

1. IRV only – this grouping was used as the IRV is the designated reference vehicle for the International Runway Friction Index (IRFI) system.
2. IRV & IMAG combined – this combination was analyzed because the IRV and the IMAG are substantially the same vehicle, and this grouping increased the size of the available data set.

Although the IRV and the IMAG were tested in a number of configurations [1], [2], only data from Configurations 3 & 7, and 1 & 16 (Table 2.1) were included in the analyses for these devices, respectively (Table 2.1). It should also be noted that the IRV and IMAG provide friction coefficients obtained from both torque and force measurements. Both friction coefficients were used in the analyses.

Table 2.1: Device Configurations Included in the Analyses

Device	TC SFT'79	IMAG	IRV
Configuration #	3	3 & 7	1 & 16
Tire Type	Smooth ASTM E1551 Tire	PIARC SmoothTire	PIARC SmoothTire
Inflation Pressure (kPa)	690	150 & 165, respectively	165 & 150, respectively
Vertical Load (kN)	1400	1800	1800
Slip ratio (%)	12	15	15
Self-Wetting On ?	no	no	no

2.2 Surfaces Selected

2.2.1 Surfaces Currently in the AIP

Currently, CRFI values are given in the AIP [5] for the surfaces shown in Figure 2.1.

RUNWAY SURFACE CONDITION (RSC) AND CRFI EQUIVILENT

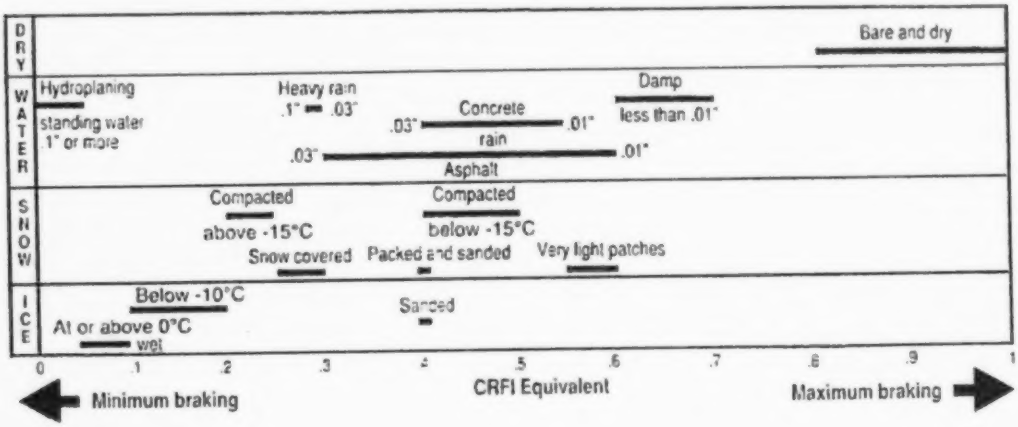


Figure 2.1: CRFIs Given in the AIP [5] for Various Surfaces

2.2.2 Surfaces Selected for the Updated AIP

The available data were first analyzed in relation to the surface conditions shown in Figure 2.1 ([1], [3], [4], see also Appendix C). It was decided that:

(a) The surfaces listed below were selected for inclusion in this study:

- bare ice
- bare packed snow
- sanded ice
- sanded packed snow
- loose snow on various substrates – previous analyses [2] showed that CRFIs in this case were dependent on both the depth of the loose snow and the type of substrate. As a result, this category was sub-divided as follows:
    i. depth ranges – CRFIs were determined for snow depth ranges of:
    - 0 to 3 mm: in this range, CRFIs reduced rapidly with increasing snow depth (on pavement) as the surface "seen" by the tire effectively changed from "pavement" to "snow" as the snow depth increased (Figure 2.2).

- >3 to 25 mm: in this range, the CRFI was effectively independent of snow depth (for loose snow on pavement). Twenty five mm was set as the upper depth limit, as this is the maximum snow depth at which decelerometers are considered to provide reliable results.

ii. substrates – CRFIs were determined for loose snow on pavement, ice, and packed snow. These three substrates were selected as they all may occur at airport runways, and previous analyses [2] showed different trends for them, with respect to the relationship between CRFI and snow depth.

(b) The surfaces listed below should not be included in this study:

- wet – this surface was not included as it is not limited to winter conditions, and the data sources used for this project contain relatively little information for CRFIs on wet surfaces. Furthermore, CRFIs on wet surfaces are speed-dependent.
- dry – this surface was beyond the scope of this study, as very little data are available from the winter testing regarding this, and it is not limited to wintertime.
- slush – decelerometers are not considered to provide reliable results on slush.

(c) CRFIs would not be provided for different surface temperature ranges, as is currently the case for the AIP (Figure 2.1) because the available data (e.g., [2], [3], [4] – see also Appendix C) showed that CRFIs are not related to the surface temperature. Instead, it was decided that the CRFIs produced in this project would be intended to be applicable to all surface temperatures.

The case where the surface is at the melting point was flagged as one where CRFIs could be slipperier than those at colder temperatures. This might be expected as phase changes of the snow or ice may occur, which would produce a water film. Because the available data were inadequate to define CRFIs for surfaces at the melting point, a note was added to this effect in the insert prepared for the updated AIP (section 3).

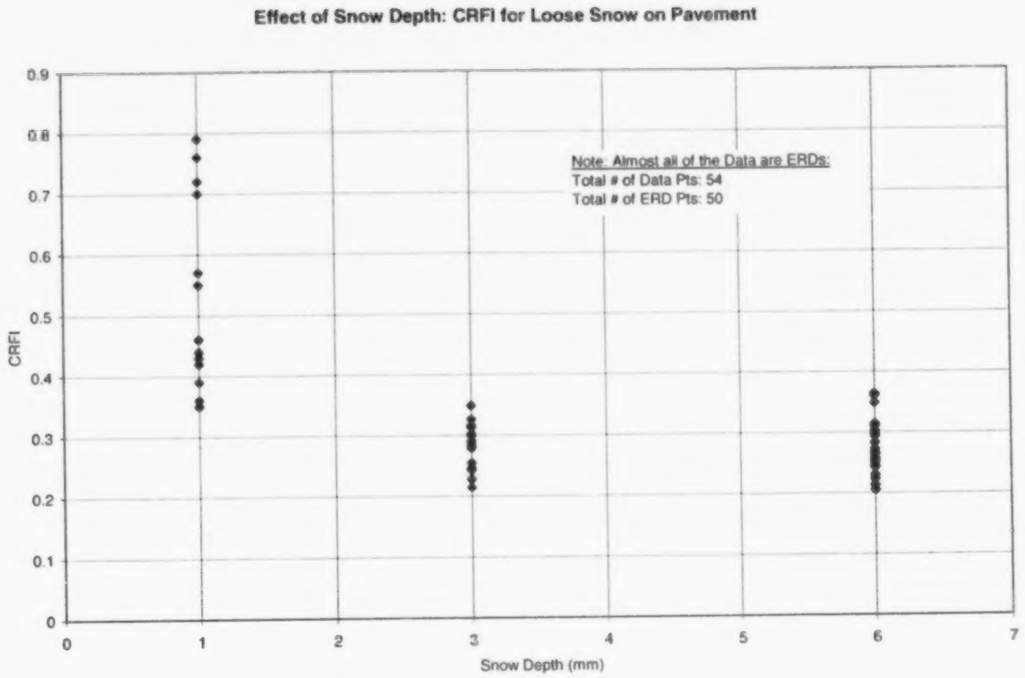


Figure 2.2: Effect of Snow Depth: 2002 [3] and 2003 [4] Decelerometer Data for Loose Snow on Pavement

2.3 Data Sources

2.3.1 Data Sources

The data used for this project were obtained from two main sources:

(a) tests done within the main JWRFMP – these data are included in the database that has been produced from the JWRFMP [1].

(b) tests done with decelerometers in 2002 [3] and 2003 [4] at various airports. These data are listed in the respective reports.

For completeness, the full data set used for this project is listed in Appendix A.

2.3.2 Data from the Joint Winter Runway Friction Measurement Program

These data were obtained by querying the database for the JWRFMP [1]. Database search parameters were specified as follows:

(a) Year and site – all years and sites were included in all searches to maximize the size of the data set.

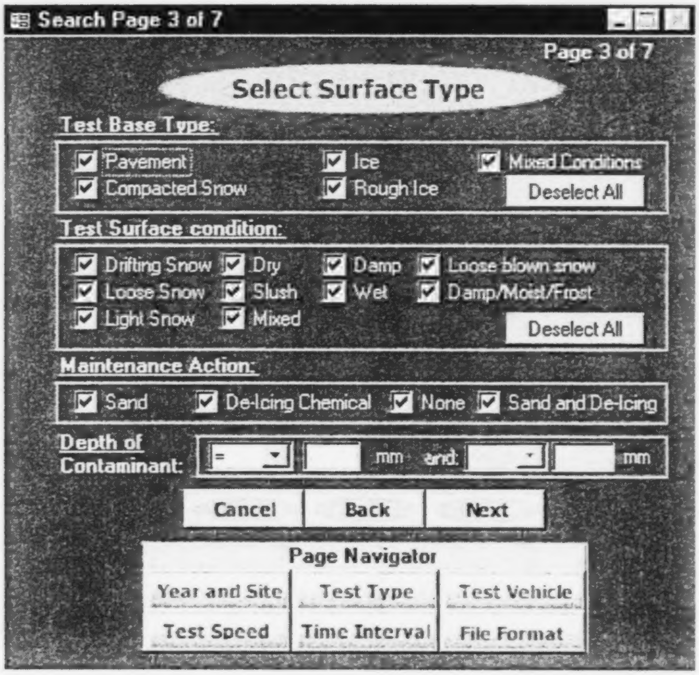
(b) Speed – all speeds were included in all searches. This was done as previous analyses (e.g., [6]) have shown that friction coefficients on winter surfaces are not dependent on speed. The data set was maximized by including all speeds.

(c) Surface and base conditions – several cases were investigated as described in section 2.2. The full range of surface conditions available in the database is illustrated in Figure 2.3.

(d) Devices – the analyses were limited to the friction coefficients measured by the ERD, the TC SFT'79, the IRV, and the IMAG (section 2.1).

(e) Time interval between individual friction readings – all readings were included. The results were not partitioned by time interval.

(f) Track section on which the average friction coefficient is computed – the analyses were done using average friction coefficients for the whole track section, as opposed to 100 m sections (which is the other option in the database search wizard). This selection was made because it maximized the size of the data set, as only "whole track" data were recorded during the early years of the JWRFMP.



Search Page 3 of 7

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Select Surface Type

Test Base Type:
☑ Pavement ☑ Ice ☑ Mixed Conditions
☑ Compacted Snow ☑ Rough Ice

Test Surface condition:
☑ Drifting Snow ☑ Dry ☑ Damp ☑ Loose blown snow
☑ Loose Snow ☑ Slush ☑ Wet ☑ Damp/Moist/Frost
☑ Light Snow ☑ Mixed

Maintenance Action:
☑ Sand ☑ De-Icing Chemical ☑ None ☑ Sand and De-Icing

Depth of Contaminant: = mm and: mm

Figure 2.3: Selectable Base and Surface Conditions in the Database Search Wizard [1]

(a) Year and site – all years and sites were included in all searches to maximize the size of the data set.

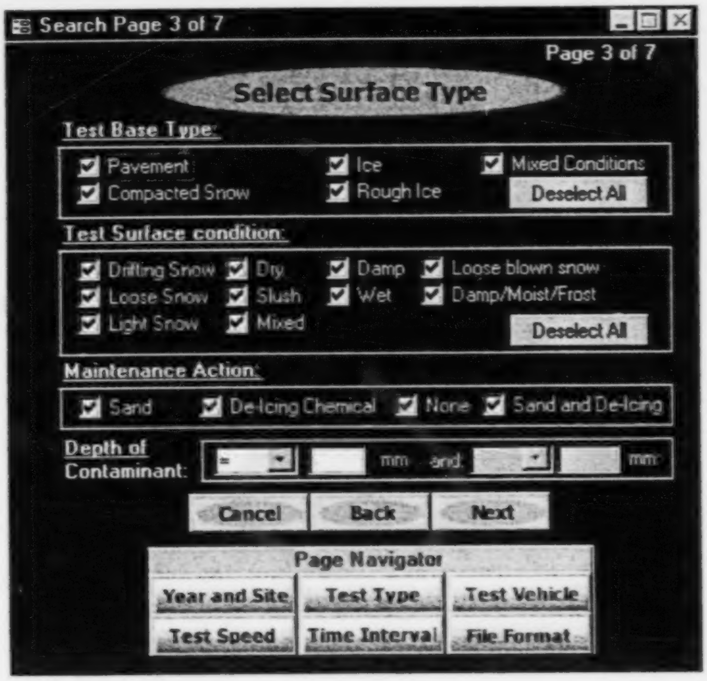
(b) Speed – all speeds were included in all searches. This was done as previous analyses (e.g., [6]) have shown that friction coefficients on winter surfaces are not dependent on speed. The data set was maximized by including all speeds.

(c) Surface and base conditions – several cases were investigated as described in section 2.2. The full range of surface conditions available in the database is illustrated in Figure 2.3.

(d) Devices – the analyses were limited to the friction coefficients measured by the ERD, the TC SFT'79, the IRV, and the IMAG (section 2.1).

(e) Time interval between individual friction readings – all readings were included. The results were not partitioned by time interval.

(f) Track section on which the average friction coefficient is computed – the analyses were done using average friction coefficients for the whole track section, as opposed to 100 m sections (which is the other option in the database search wizard). This selection was made because it maximized the size of the data set, as only "whole track" data were recorded during the early years of the JWRFMP.


Search Page 3 of 7
Page 3 of 7
Select Surface Type
Deselect All
Deselect All
Cancel
Back
Next
Page Navigator
Year and Site
Test Type
Test Vehicle
Test Speed
Time Interval
File Format

Test Base Type:
☑ Pavement ☑ Ice ☑ Mixed Conditions
☑ Compacted Snow ☑ Rough Ice

Test Surface condition:
☑ Drifting Snow ☑ Dry ☑ Damp ☑ Loose blown snow
☑ Loose Snow ☑ Slush ☑ Wet ☑ Damp/Moist/Frost
☑ Light Snow ☑ Mixed

Maintenance Action:
☑ Sand ☑ De-Icing Chemical ☑ None ☑ Sand and De-Icing

Depth of Contaminant: = mm and mm

Figure 2.3: Selectable Base and Surface Conditions in the Database Search Wizard [1]

2.3.3 Decelerometer Test Programs

Data from the following test programs were included:

(a) Data collected during the 2002 winter at North Bay airport [3]. These data were collected during a project conducted to investigate the effect of vehicle parameters on the friction coefficients measured by decelerometers. These data were partitioned as follows for this project:

- decelerometer types – all were included. However, most of the data were from ERDs.
- vehicles – all types were included, as Transport Canada (TC) does not limit the vehicle type that can be used as a platform for CRFI measurements made with decelerometers.
- ABS on vs. off – only the "ABS off" data were included, as TC currently does not allow CRFI measurements to be made with the vehicle's ABS activated.
- weight distribution – only the "as-is" data were included. The data obtained with a 50:50 weight distribution for the half ton pickup truck were not included, as this was a special case in which the truck was loaded with weights to achieve this weight distribution.
- surfaces – all were included. They were subdivided into categories.
- temperatures – all were included. They were subdivided into categories.
- CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(b) Data collected during the 2003 winter at North Bay airport [4]. These tests were performed to investigate the effect of having ABS on or off on the friction coefficients measured by decelerometers. These data were partitioned as follows for this analysis:

- decelerometer types – all were included. However, most of the data were from ERDs.
- vehicles – all were included.
- ABS on vs. off – only the "ABS off" data were included.
- surfaces – all were included. They were subdivided into categories.
- temperatures – all were included. They were subdivided into categories.
- CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(c) Data collected during the 2003 winter as part of CRFI Quality Assurance tests [4]. Data were collected at five airports. These data were partitioned as follows:

- decelerometer types – all of the data were from ERDs. Unreliable data (e.g., from TC's ERD Mk III [4]) were not included.
- vehicles and operators – all data were included.
- airports, circuits and runs – all data were included.
- surfaces – all were included. They were subdivided into categories.
- CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

2.4 Analysis Approach

2.4.1 Outliers

Previous analyses using the JWRFMP database [2] showed that the CRFIs measured for a given surface type varied greatly. For example, CRFIs up to about 0.7 were measured for bare ice (Figure 2.4). This range may not be representative for various reasons such as:

(a) surfaces were non-uniform in some cases for the JWRFMP, which made it difficult to describe or classify them. Also, the surfaces changed during testing due to the passage of the friction-measuring vehicles. For example, the high CRFIs seen for bare ice (of about 0.7 – Figure 2.4) might have been produced if the surface had consisted of a thin, patchy ice layer overlaying pavement, and if the particular device (the IMAG in this case – Figure 2.4) had been one of the last ones to traverse the surface.

(b) because the JWRFMP is a research program, it included some tests on surfaces that were not operational ones.

Therefore, it was decided that the CRFI information to be provided in the AIP should not span the full range of the measured data.

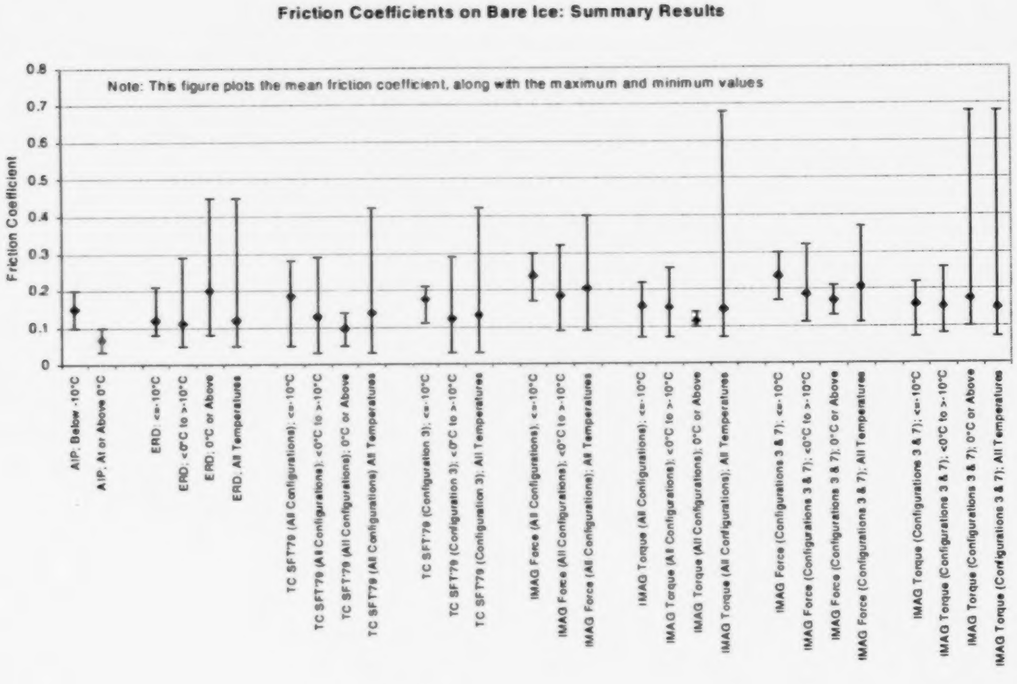


Figure 2.4: CRFIs Measured for Bare Ice (after [2])

2.4.2 Treatment of Outliers and Analysis Approach

Appropriate measures for limiting the CRFI range were considered and evaluated (Appendix C). It was decided to use a two-step process:

(a) Step 1 – implement "reality" checks in accordance with pre-set CRFI limits. For example, it is well known that the maximum CRFI of 0.68 in Figure 2.3 is too high for ice and that the "0.68" is probably a pavement surface. CRFI limits were set for each surface as listed in Table 2.2. Outliers were removed from the data set used for this project.

(b) Step 2 – reduce the CRFI range shown in the AIP to some fraction of the whole distribution. After evaluating several methods (Appendix C), it was decided:

- to include a range of CRFIs that spanned 95% of the measured data. For a normal distribution, this would be equivalent to about +/- 2 standard deviations from the mean.
- to calculate the CRFI range on either side of the median for the distribution because most of the measured CRFI distributions were not normal. (This was done because a simple addition and subtraction of, say, +/- 2 standard deviations would have produced CRFIs less than zero in many cases, which is clearly unreasonable.)

Table 2.2: Expected Minimum and Maximum CRFIs for Various Surfaces

Surface	Lower CRFI Limit	Upper CRFI Limit
Bare Ice	No Limit	0.3
Bare Packed Snow	0.1	0.4
Sanded Ice	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Ice: Depth – 3mm or Less	No Limit	0.4
Loose Snow on Ice: Depth – 3 to 25 mm	No Limit	0.4
Loose Snow on Packed Snow: Depth – 3mm or Less	0.1	0.4
Loose Snow on Packed Snow: Depth – 3 to 25 mm	0.1	0.4
Loose Snow on Pavement: Depth – 3mm or Less	0.1	Dry Pavement
Loose Snow on Pavement: Depth – 3 to 25 mm	0.1	Dry Pavement

3. CRFIs MEASURED WITH DECELEROMETERS

3.1 Results

3.1.1 Sample Distributions and Results

Plots were prepared showing the distributions of CRFIs measured using decelerometers on each of the candidate surfaces (listed in section 2.2). Figures 3.1 and 3.2 show samples for CRFIs on bare ice and bare packed snow, respectively. A full set of plots is provided in Appendix B.

The plots show:

(a) the measured CRFI distribution; and

(b) the CRFI range representing:

- +/- 1 standard deviation from the median of the population; and
- +/- 2 standard deviations from the median of the population.

It should be noted that, as described in section 2.4, the CRFI range selected for inclusion in the updated AIP was +/- 2 standard deviations from the median of the population. The other range (i.e., 1 standard deviation from the median of the population) was only included on the plots to give added information.

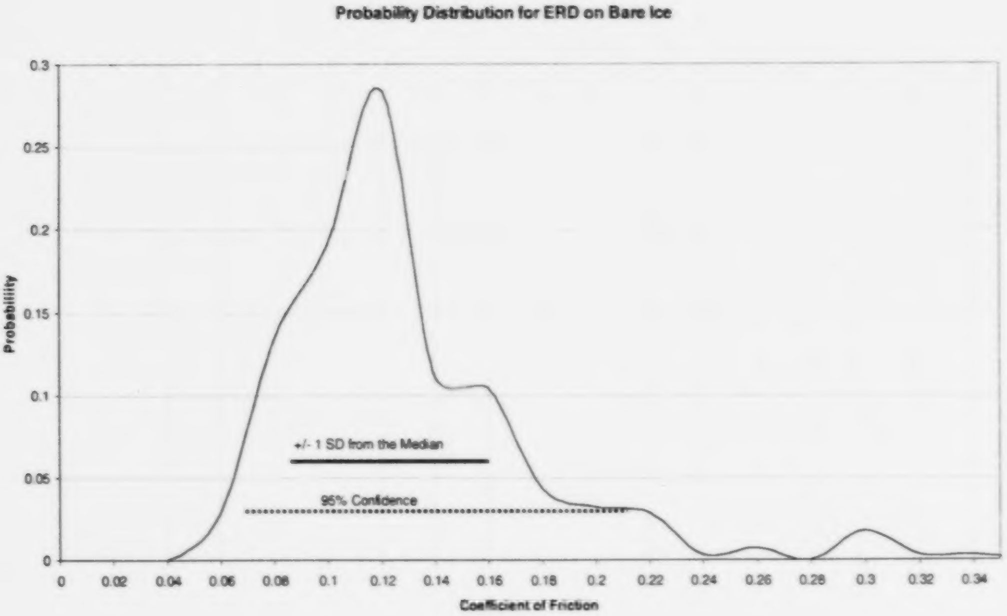


Figure 3.1: CRFIs for Decelerometers on Bare Ice

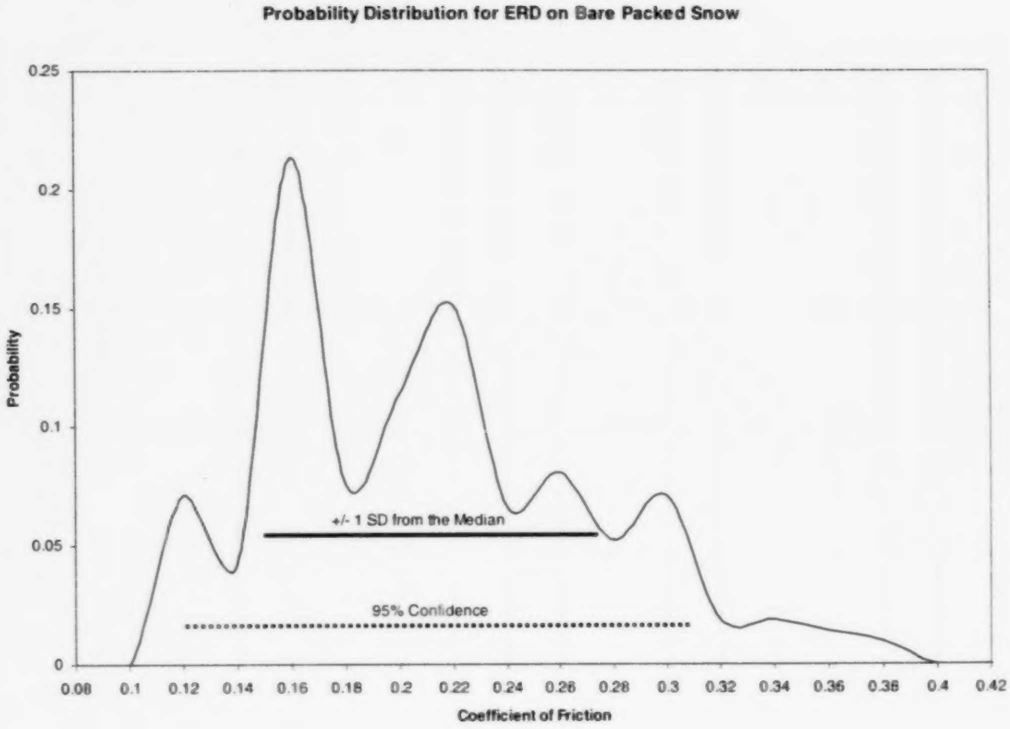


Figure 3.2: CRFIs for Decelerometers on Bare Packed Snow

3.1.2 Summarized Results

Table 3.1 summarizes the CRFI data obtained with decelerometers on each of the candidate surfaces.

Table 3.1: CRFIs Measured with Decelerometers on the Candidate Surfaces

Surface	# of Obs.[2]	Mean CRFI	Median CRFI	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	278	0.123	0.110	0.085 to 0.160	0.070 to 0.215
Bare Packed Snow	211	0.203	0.190	0.145 to 0.275	0.120 to 0.310
Sanded Ice	28	0.244	0.235	0.205 to 0.290	0.185 to 0.350
Sanded Packed Snow	70	0.346	0.335	0.285 to 0.435	0.225 to 0.470
Loose Snow on Pavement: <= 3 mm Depth	38	0.379	0.325	0.210 to 0.555	0.160 to 0.760
Loose Snow on Pavement: >3 to <= 25 mm Depth	33	0.293	0.285	0.240 to 0.365	0.205 to 0.390
Loose Snow on Ice: <= 3 mm Depth	15	0.253	0.265	0.210 to 0.280	0.205 to 0.300
Loose Snow on Ice: >3 to <= 25 mm Depth	43	0.175	0.180	0.140 to 0.220	0.115 to 0.245
Loose Snow on Packed Snow: <= 3 mm Depth	4	0.305	n/a[3]	Not avail:Range[3] = 0.280 to 0.350	Not avail:Range[3] = 0.280 to 0.350
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	58	0.265	0.250	0.215 to 0.325	0.190 to 0.365

Legend:

1. σ: Standard deviation
2. Obs.: Observations
3. Neither the median nor the CRFI ranges for +/- 1 and 2 σ were calculated as there were too few data points. The range given is the range from the maximum to the minimum measured CRFI.

3.2 Suggested Insert for the AIP

The suggested insert for use in updating the AIP is shown in Figure 3.3.

It should be noted that owing to a lack of data, or paucity of data, for some cases, the values on Figure 3.1 had to be established using some judgment as follows:

(a) loose snow (of <= 3 mm depth) on ice – only a small number of data points are available for this case (Table 3.1). Consequently, the values for this surface were established by combining the available data for bare ice and for loose snow (of <= 3 mm depth) on ice. This produced a data subset with the following values:

- number of observations: 293;
- mean & median CRFI: 0.130 & 0.110, respectively;
- range for +/- 1 standard deviation: 0.090 to 0.175; and
- range for +/- 2 standard deviations: 0.075 to 0.270.

(b) loose snow (of <= 3 mm depth) on packed snow – no data are available for this surface. The values in Figure 3.1 for this case were selected by using the same ones established for bare packed snow.

The CRFI depends on the surface type as shown in Table 4a. It should be noted that:

(a) the CRFI values given in Table 4a are applicable to all temperatures. Extensive measurements have shown that the CRFI is not correlated with the surface temperature. The case where the surface temperature is just at the melting point (i.e., about 0°C) may be an exception as a water film may form by surface melting, which could induce slippery conditions with CRFIs less than those in Table 4a.

(b) the CRFI may span a range of values for various reasons, such as variations in texture among surfaces within a given surface class. The expected maximum and minimum CRFIs for various surfaces are listed in Table 4b. Note that these values are based on a combination of analyses of extensive measurements and sound engineering judgment.

(c) the largest range in CRFI is to be expected for a thin layer (3 mm or less in thickness) of loose snow on pavement (Table 4a). This variation may occur due to: (i) non-uniform snow coverage, and/or (ii) the tires breaking through the thin layer. In either case, the surface presented to the aircraft may range from snow to pavement.

Table 4a **Expected Range of CRFIs by Surface Type**

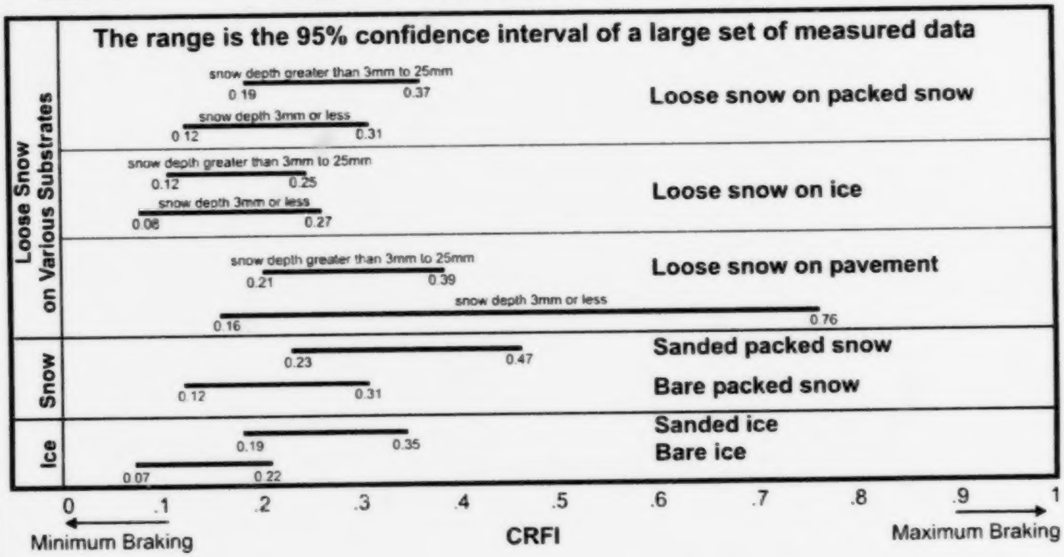


Table 4b **Expected Minimum and Maximum CRFIs for Various Surfaces**

Surface	Lower CRFI Limit	Upper CRFI Limit
Bare Ice	No Limit	0.3
Bare Packed Snow	0.1	0.4
Sanded Ice	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Ice: Depth - 3mm or Less	No Limit	0.4
Loose Snow on Ice: Depth - 3 to 25 mm	No Limit	0.4
Loose Snow on Packed Snow: Depth - 3mm or Less	0.1	0.4
Loose Snow on Packed Snow: Depth - 3 to 25 mm	0.1	0.4

Figure 3.3: Suggested Insert for the AIP

4. GENERAL ANALYSES

4.1 Results for the SFT

Distributions are plotted for the TC SFT'79 data for each surface in Appendix B. Figures 4.1 and 4.2 show sample results for bare ice and bare packed snow, respectively.

Table 4.1 summarizes the friction coefficient results for the TC SFT'79.

Table 4.1: Friction Coefficients Measured with the SFT on the Candidate Surfaces

Surface	# of Obs.[2]	Mean Friction Coefficient	Median Friction Coefficient	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	170	0.128	0.120	0.050 to 0.220	0.075 to 0.190
Bare Packed Snow	151	0.227	0.225	0.185 to 0.275	0.160 to 0.320
Sanded Ice	No Data	No Data	No Data	No Data	No Data
Sanded Packed Snow	No Data	No Data	No Data	No Data	No Data
Loose Snow on Pavement: <= 3 mm Depth	9	0.111	0.110	0.105 to 0.125	0.105 to 0.130
Loose Snow on Pavement: >3 to <= 25 mm Depth	36	0.210	0.160	0.120 to 0.390	0.140 to 0.310
Loose Snow on Ice: <= 3 mm Depth	3	0.160	n/a[3]	Not avail:Range[3] = 0.150 to 0.170	Not avail:Range[3] = 0.150 to 0.170
Loose Snow on Ice: >3 to <= 25 mm Depth	38	0.145	0.150	0.075 to 0.290	0.095 to 0.165
Loose Snow on Packed Snow: <= 3 mm Depth	No Data	No Data	No Data	No Data	No Data
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	10	0.246	0.250	Not avail:Range[3] = 0.235 to 0.260	Not avail:Range[3] = 0.235 to 0.260

Legend:

1. σ: Standard deviation
2. Obs.: Observations
3. Neither the median nor the friction coefficient ranges for +/- 1 and 2 σ were calculated as there were too few data points. The range given is the range from the maximum to the minimum measured friction coefficient.

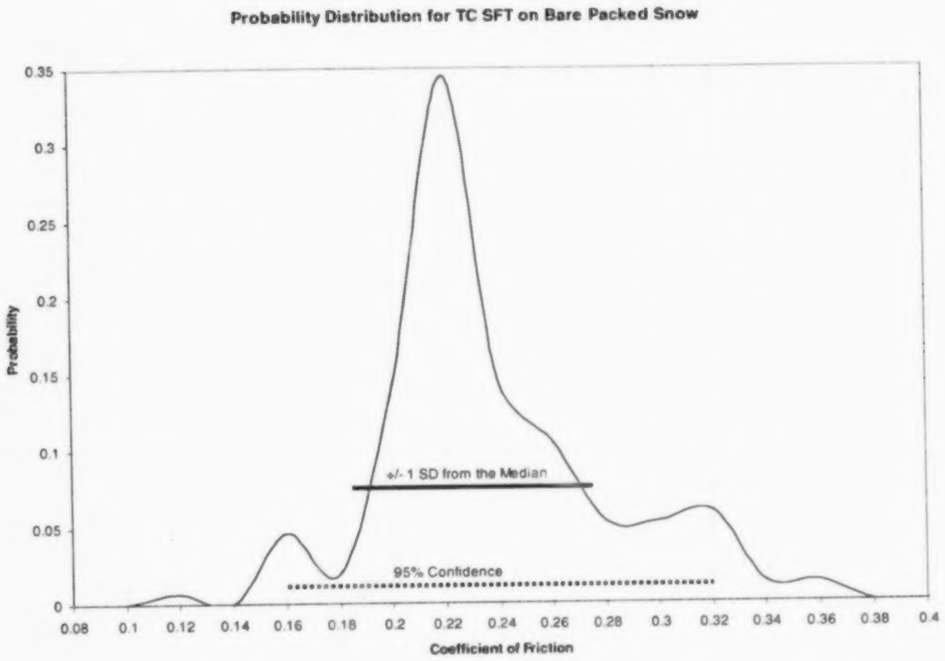


Figure 4.1: Friction Coefficients for TC SFT'79 on Packed Snow

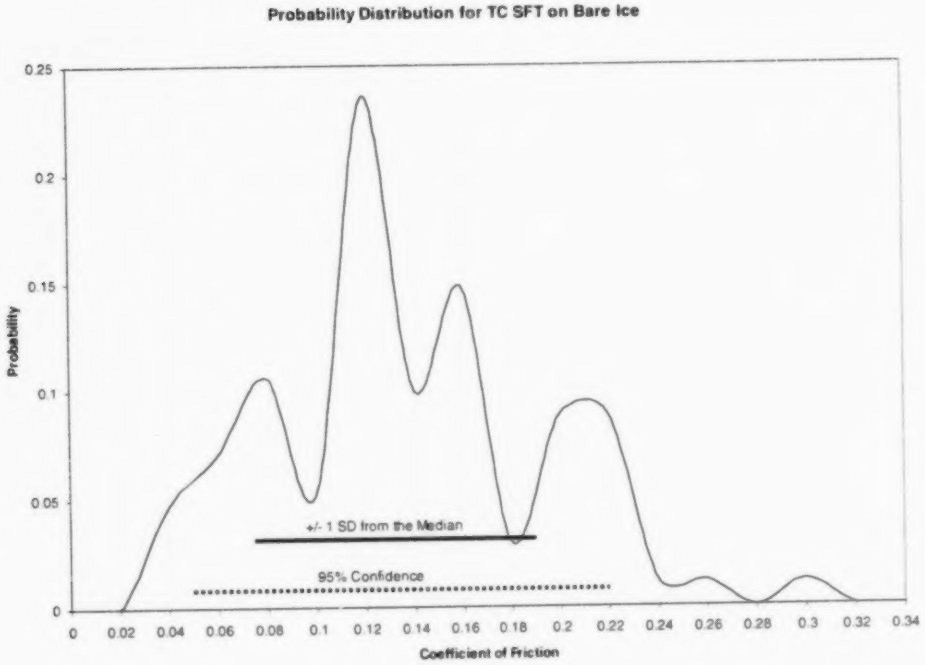


Figure 4.2: Friction Coefficients for TC SFT'79 on Bare Ice

4.2 Results for the IRV

The IRV outputs two friction coefficients that are based on either: (a) force measurements, or (b) torque measurements. These data are termed IRV (Force) and IRV (Torque), respectively, in this report. Distributions are plotted for all IRV data for each surface in Appendix B.

Tables 4.2 and 4.3 summarize the friction coefficient results for the IRV (Force) and the IRV (Torque), respectively.

4.3 Results for the Combination of the IRV and the IMAG

The combination of the IRV and the IMAG was analyzed because these are essentially the same device, and the size of the available data set was maximized by including both devices. The same convention used regarding IRV (Force) and IRV (Torque) (see section 4.2) was used for the combined data set.

Distributions are plotted for all of the combined IRV/IMAG data for each surface in Appendix B.

Tables 4.4 and 4.5 summarize the friction coefficient results for the combined data sets for IRV (Force) and IMAG (Force), and IRV (Torque) and IMAG (Torque), respectively.

The friction coefficients determined for the combined data sets agree closely with those determined using only the IRV (Force) and IRV (Torque) data. Compare Tables 4.2 and 4.4, and Tables 4.3 and 4.5, respectively. Consequently, the combined data set has been used as the basis for all subsequent discussions in this report regarding the CRFIs measured with the IRV (Force) and (IRV (Torque) devices.

Figures 4.3 and 4.4 show friction coefficient distributions for the combined data set for the IRV (Force) and IMAG (Force) on bare ice and bare packed snow, respectively. Figures 4.5 and 4.6 show similar information for the combined data set of IRV (Torque) and IMAG (Torque) respectively. Friction coefficient distributions are plotted in Appendix B for all cases and surfaces.

Table 4.2: Friction Coefficients Measured with the IRV (Force) on the Candidate Surfaces

Surface	# of Obs.[2]	Mean Friction Coefficient	Median Friction Coefficient	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	177	0.174	0.160	0.120 to 0.235	0.080 to 0.275
Bare Packed Snow	126	0.248	0.240	0.215 to 0.290	0.200 to 0.315
Sanded Ice	4	0.387	0.390	Not avail:Range[3] = 0.370 to 0.400	Not avail:Range[3] = 0.370 to 0.400
Sanded Packed Snow	3	0.353	n/a[3]	Not avail:Range[3] = 0.350 to 0.360	Not avail:Range[3] = 0.350 to 0.360
Loose Snow on Pavement: <= 3 mm Depth	3	0.207	n/a[3]	Not avail:Range[3] = 0.190 to 0.220	Not avail:Range[3] = 0.190 to 0.220
Loose Snow on Pavement: >3 to <= 25 mm Depth	36	0.284	0.295	0.230 to 0.340	0.210 to 0.375
Loose Snow on Ice: <= 3 mm Depth	1	0.220[3]	n/a[3]	Range[3] not available	Range[3] not available
Loose Snow on Ice: >3 to <= 25 mm Depth	8	0.294	0.305	0.280 to 0.325	0.185 to 0.345
Loose Snow on Packed Snow: <= 3 mm Depth	No Data	No Data	No Data	No Data	No Data
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	5	0.198	n/a[3]	Not avail:Range[3] = 0.190 to 0.200	Not avail:Range[3] = 0.190 to 0.200

Legend:

1. σ: Standard deviation
2. Obs : Observations
3. Neither the median nor the friction coefficient ranges for +/- 1 and 2 σ were calculated as there were too few data points. The range given is the range from the maximum to the minimum measured friction coefficient.

Table 4.3: Friction Coefficients Measured with the IRV (Torque) on the Candidate Surfaces

Surface	# of Obs.[2]	Mean Friction Coefficient	Median Friction Coefficient	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	180	0.120	0.110	0.075 to 0.165	0.055 to 0.215
Bare Packed Snow	126	0.203	0.200	0.160 to 0.250	0.150 to 0.285
Sanded Ice	5	0.378	0.380	Not avail:Range[3] = 0.350 to 0.400	Not avail:Range[3] = 0.350 to 0.400
Sanded Packed Snow	3	0.280	n/a[3]	Not avail:Range[3] = 0.280 to 0.280	Not avail:Range[3] = 0.280 to 0.280
Loose Snow on Pavement: <= 3 mm Depth	3	0.113	n/a[3]	Not avail:Range[3] = 0.110 to 0.120	Not avail:Range[3] = 0.110 to 0.120
Loose Snow on Pavement: >3 to <= 25 mm Depth	35	0.203	0.205	0.125 to 0.265	0.110 to 0.345
Loose Snow on Ice: <= 3 mm Depth	1	0.120[3]	n/a[3]	Range[3] not available	Range[3] not available
Loose Snow on Ice: >3 to <= 25 mm Depth	8	0.206	0.210	0.185 to 0.245	0.110 to 0.275
Loose Snow on Packed Snow: <= 3 mm Depth	No Data	No Data	No Data	No Data	No Data
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	5	0.118	n/a[3]	Not avail:Range[3] = 0.110 to 0.140	Not avail:Range[3] = 0.110 to 0.140

Legend:

1. σ: Standard deviation
2. Obs: Observations
3. Neither the median nor the friction coefficient ranges for +/- 1 and 2 σ were calculated as there were too few data points. The range given is the range from the maximum to the minimum measured friction coefficient.

Table 4.4: Friction Coefficients for the Combination of IRV (Force) and IMAG (Force)

Surface	# of Obs.[2]	Mean Friction Coefficient	Median Friction Coefficient	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	343	0.188	0.185	0.145 to 0.240	0.105 to 0.280
Bare Packed Snow	261	0.257	0.245	0.215 to 0.305	0.200 to 0.380
Sanded Ice	4	0.387	0.390	Not avail:Range[3] = 0.370 to 0.400	Not avail:Range[3] = 0.370 to 0.400
Sanded Packed Snow	3	0.353	n/a[3]	Not avail:Range[3] = 0.350 to 0.360	Not avail:Range[3] = 0.350 to 0.360
Loose Snow on Pavement: <= 3 mm Depth	22	0.310	0.224	0.150 to 0.580	0.150 to 0.875
Loose Snow on Pavement: >3 to <= 25 mm Depth	92	0.273	0.280	0.205 to 0.350	0.160 to 0.380
Loose Snow on Ice: <= 3 mm Depth	1	0.220[3]	n/a[3]	Range[3] not available	Range[3] not available
Loose Snow on Ice: >3 to <= 25 mm Depth	38	0.232	0.220	0.180 to 0.320	0.160 to 0.345
Loose Snow on Packed Snow: <= 3 mm Depth	No Data	No Data	No Data	No Data	No Data
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	11	0.223	0.205	0.200 to 0.260	0.190 to 0.260

Table 4.5: Friction Coefficients for the Combination of IRV (Torque) and IMAG (Torque)

Surface	# of Obs.[2]	Mean Friction Coefficient	Median Friction Coefficient	CRFI Range for +/- 1 σ[1]	CRFI Range for +/- 2 σ[1]
Bare Ice	394	0.134	0.140	0.080 to 0.210	0.090 to 0.180
Bare Packed Snow	310	0.195	0.250	0.155 to 0.245	0.140 to 0.300
Sanded Ice	10	0.307	0.350	0.175 to 0.390	0.175 to 0.405
Sanded Packed Snow	3	0.280	n/a[3]	Not avail:Range[3] = 0.280 to 0.280	Not avail:Range[3] = 0.280 to 0.280
Loose Snow on Pavement: <= 3 mm Depth	11	0.374	0.350	0.105 to 0.795	0.105 to 0.830
Loose Snow on Pavement: >3 to <= 25 mm Depth	102	0.187	0.185	0.110 to 0.265	0.105 to 0.310
Loose Snow on Ice: <= 3 mm Depth	1	0.120[3]	n/a[3]	Range[3] not available	Range[3] not available
Loose Snow on Ice: >3 to <= 25 mm Depth	54	0.184	0.185	0.110 to 0.250	0.150 to 0.235
Loose Snow on Packed Snow: <= 3 mm Depth	No Data	No Data	No Data	No Data	No Data
Loose Snow on Packed Snow: >3 to <= 25 mm Depth	11	0.151	0.145	Not avail:Range[3] = 0.105 to 0.185	Not avail:Range[3] = 0.105 to 0.185

Legend for Tables 4.4 and 4.5:

1. σ: Standard deviation
2. Obs: Observations
3. Neither the median nor the friction coefficient ranges for +/- 1 and 2 σ were calculated as there were too few data points. The range given is the range from the maximum to the minimum measured friction coefficient.

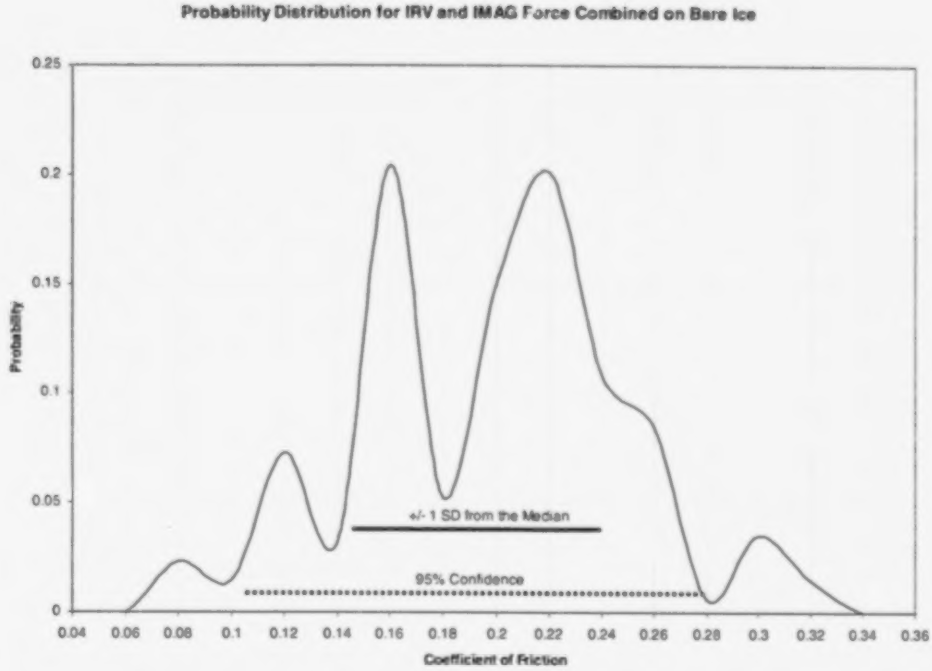


Figure 4.3: Friction Coefficients for IRV (Force) and IMAG (Force) on Bare Ice

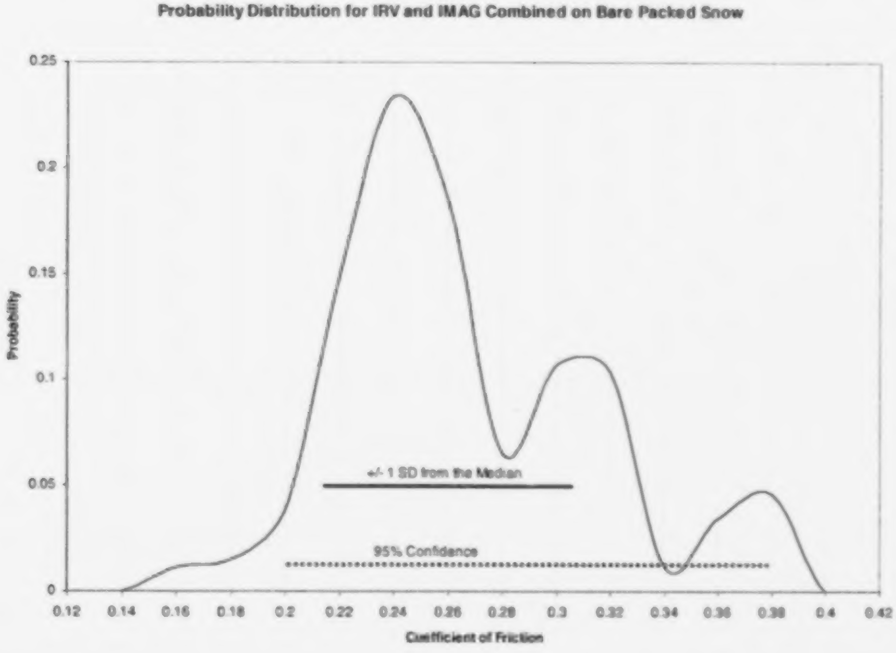


Figure 4.4: Friction Coefficients for IRV (Force) and IMAG (Force) on Bare Packed Snow

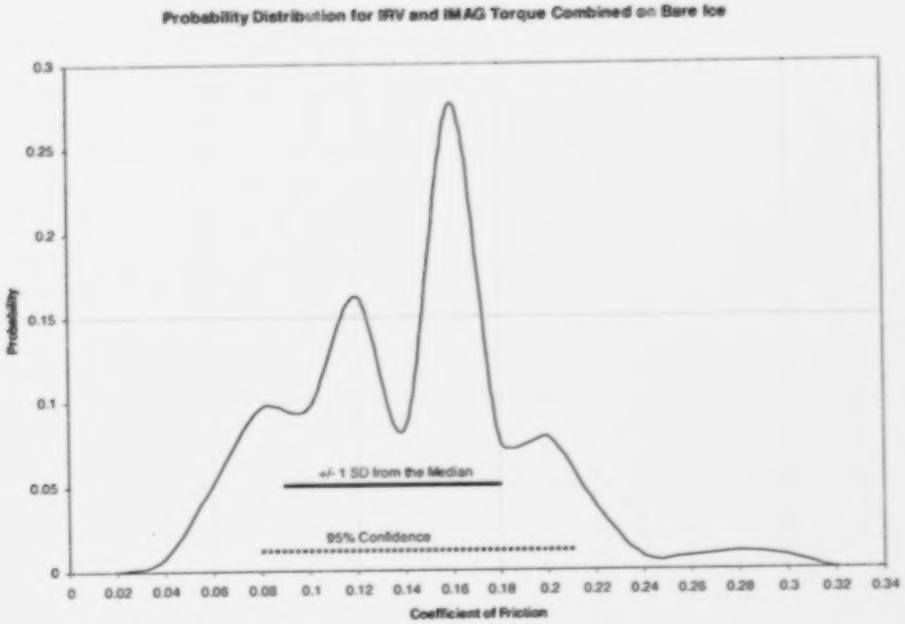


Figure 4.5: Friction Coefficients for IRV (Torque) and IMAG (Torque) on Bare Ice

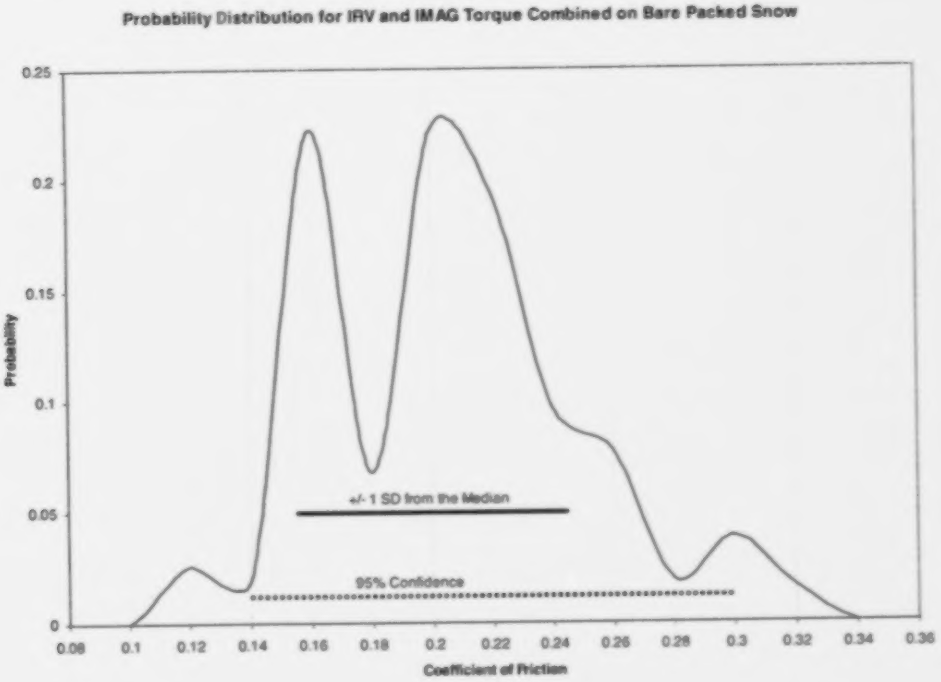


Figure 4.6: Friction Coefficients for IRV (Torque) and IMAG (Torque) on Bare Packed Snow

4.4 Comparison Among Devices

The CRFIs determined for decelerometers, the friction coefficients for TC SFT'79 and the combination of the IRV and IMAG (both Force and Torque) are compared in Figure 4.7, for the surfaces where the large data sets were relatively large. It is evident that:

(a) IRV and IMAG Combined – Force vs. Torque Data – the friction coefficients provided by the force measurements were always higher than those from the torque data. This follows the expected trend as the force data from these devices are obtained by adding the drag force onto the torque data, and re-computing the friction coefficient.

(b) Friction coefficient variations among devices and surfaces:
- for all surfaces considered, the mean friction coefficients span a range of about 0.1;
- the minimum friction coefficients (i.e., 2 standard deviations below the population median) are quite consistent, as they are within about 0.05 of each other;
- the maximum friction coefficients (i.e., 2 standard deviations above the population median) can vary considerably, depending on the surface. The overall variation would be reduced if the IRV and IMAG (Force) data were not included in the comparison.

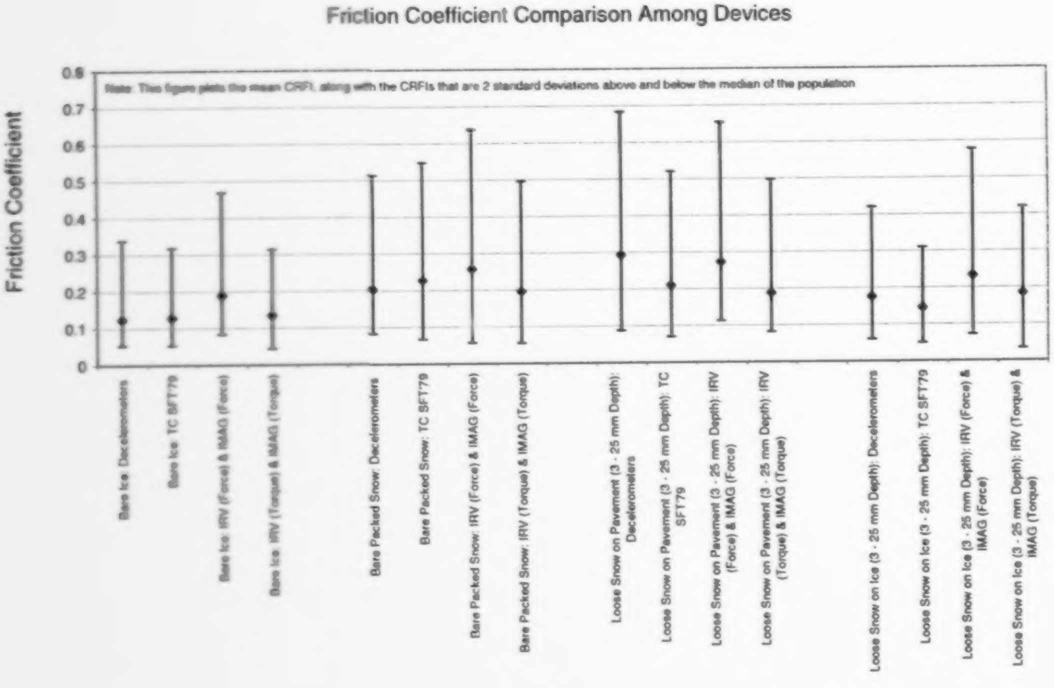


Figure 4.7: Friction Coefficient Comparison Among Devices

4.5 General Discussion of the Factors Causing Friction Coefficient Variations on Surfaces

4.5.1 General

Significant coefficient of friction variations have been observed for each surface class.

There are many factors that cause the coefficient of friction on a given surface to vary. The main one can be ascribed to the properties (i.e., nature, texture, hardness, uniformity, etc.) of the surface condition itself, which includes both the surface condition and the substrate.

The effect of texture is to be expected. For example, smooth ice has a lower friction than rough ice. Compacted snow that is smooth will have a lower friction than a compacted snow surface that is rough.

The hardness of the compacted snow (and also its density) is another factor. A very hard compacted snow surface will have a lower friction than a compacted snow surface that is less dense that allows the tires, or their tread, to penetrate the surface. Although the field data have shown the friction is insensitive to the surface temperature, it is expected temperatures close to the melting point would however, produce changes in friction, as they will begin to melt the ice and snow. This would create a thin wet film condition on the surface. A thin layer of water on ice or compacted snow is very slippery.

When sand is applied to ice and compacted snow surfaces to increase the friction, the friction changes that result depend on the amount of sand applied and again, whether the surface itself is smooth or rough.

The condition of the runway surface itself is another important factor affecting the resulting friction values, particularly when loose snow is present. Under these cases, the tires will break through the loose snow layers and make contact with the pavement itself. If the runway surface itself is relatively smooth, loose snow on the surface will bring about lower friction values compared to a runway surface that has a high aggressive friction surface.

4.5.2 Bare Ice

Coefficient of friction variations are normally the result of differences in the properties of the ice surfaces (e.g., texture; smooth ice, rough ice, very rough ice, scarified ice, etc.). A coefficient of friction at the lower end (0.07) generally is found on smooth ice at temperatures close to the freezing point. The ice begins to melt causing a wet film on the ice surface. Rough ice or ice which has been scarified results in higher coefficient of friction numbers.

4.5.3 Sanded Ice

Coefficient of friction variations on sanded ice surfaces are due to several factors, such as the ice surface itself being different (smooth or rough ice), the amount of sand applied varying, and the type of sand applied to the surface. The air temperature and the presence of solar heating may affect the coefficient of friction as well, by affecting the degree by which the sand sticks to the ice surface. At temperatures close to freezing, sand will readily bond to the ice surface itself, which will produce a higher friction surface. Increasing surface friction by using sand is limited. Generally the friction of the surface can be expected to increase up to 0.12 when sand is applied.

4.5.4 Bare Packed Snow

The hardness of the compacted snow (and also its density), the surface condition itself, (smooth or rough), and the amount of traffic on the compacted snow all cause a range of friction coefficients to occur. As traffic on the surface increases, the surface becomes more polished (smoothened) which will result in a lower friction coefficient. This polishing lowers the texture, and the friction coefficient. As with ice, the compacted snow surface itself does vary. As a result, the texture of compacted snow surfaces can vary widely, from quite smooth to quite rough.

4.5.5 Sanded Packed Snow

Sand is applied to a compacted snow surface to increase its surface friction. The coefficient of friction increase achieved from sand applications depends on the condition of the compacted snow surfaces (see above), the amount of sand applied, and the type of sand used. As with ice, surface friction that can be achieved by applying sand is limited. Generally, the friction of the surface can be expected to increase by up to 0.1 when sand is applied.

4.5.6 Loose Snow on Pavement: 3 mm or Less in Depth

Loose snow conditions occur during a light snowfall or when snow drifts across the runway surface. The snow density and condition of the bare pavement are the usually the main factors that cause friction ranges to occur. When the snow is heavy, approaching a slush condition, friction coefficients will be low. In the majority of cases, the tires of the vehicle itself often break through the light snow cover and make contact with the pavement. When this occurs, the runway surface condition (smooth, rough, rubber covered, etc.) will be a factor affecting the resulting friction coefficient number. Generally, when the tires break though and contact the surface the friction coefficient number is in the higher range.

4.5.7 Loose Snow on Pavement: 3 to 25 mm Depth

The reasons for the friction range are similar to those stated above. There is one added variable, however. As the snow depth increases, the snow in front of the tires causes a drag on the tire which increases the friction number.

4.5.8 Loose Snow on Ice: 3 mm or Less in Depth

A thin layer of loose snow on ice increases the surface friction minimally, as compared to an ice surface itself. This is mainly due to the fact that the tires will penetrate the thin snow layer and make contact with the ice surface. The variance in friction coefficients is mainly due to the surface condition of the ice than the loose snow on it.

4.5.9 Loose Snow on Ice: 3 to 25 mm Depth

Loose snow on ice will tend to provide a drag force on the tires which, in turn, will result in an increase in friction coefficient. This increase is minimal, however, because even under a loose snow depth of 25 mm, the tires will begin breaking through the snow and make contact with the ice.

4.5.10 Loose Snow on Compacted Snow: 3 mm or Less in Depth

A very thin layer of loose snow on top of compacted snow does not appear to affect the friction coefficient ranges. This is probably due to the fact that the tires are breaking through the snow layer and making contact with the compacted snow surface.

4.5.11 Loose Snow on Compacted Snow: 3 to 25 mm Depth

As the snow depth increases, the drag force caused by the snow building up in front of the tires increases. The friction is increased with this increased drag.

5. CONCLUSIONS

A large set of field data has been obtained over the past eight years as part of the Joint Winter Runway Friction Measurement Program (JWRFMP) to define Canadian Runway Friction Indexes (CRFIs) on winter surfaces. The Aeronautical Information Publication (AIP) currently contains representative values for CRFIs on various surfaces, although it does not make use of the data collected as part of the JWRFMP.

In this project, the field data from the JWRFMP were analyzed to:

(a) produce material useful for updating Table 4 of the present AIP. The suggested insert for the AIP is shown in Figure 5.1 (repeated from section 3). It should be noted that the information presented in Figure 5.1 is applicable to the case where friction coefficients are measured with decelerometers.

(b) investigate the effect of surface conditions on CFRIs and friction coefficients – this has been done for the following devices:

   a. decelerometers
   b. TC SFT'79
   c. combination of the IRV and the IMAG (both force and torque measurements)

Figure 5.2 (repeated from section 4) compares the friction coefficients measured by these devices for some of the surfaces identified for inclusion in the AIP update (Figure 5.1).

The CRFI depends on the surface type as shown in Table 4a. It should be noted that:

(a) the CRFI values given in Table 4a are applicable to all temperatures. Extensive measurements have shown that the CRFI is not correlated with the surface temperature. The case where the surface temperature is just at the melting point (i.e., about 0°C) may be an exception as a water film may form by surface melting, which could induce slippery conditions with CRFIs less than those in Table 4a.

(b) the CRFI may span a range of values for various reasons, such as variations in texture among surfaces within a given surface class. The expected maximum and minimum CRFIs for various surfaces are listed in Table 4b. Note that these values are based on a combination of analyses of extensive measurements and sound engineering judgment.

(c) the largest range in CRFI is to be expected for a thin layer (3 mm or less in thickness) of loose snow on pavement (Table 4a). This variation may occur due to: (i) non-uniform snow coverage, and/or (ii) the tires breaking through the thin layer. In either case, the surface presented to the aircraft may range from snow to pavement.

Table 4a **Expected Range of CRFIs by Surface Type**

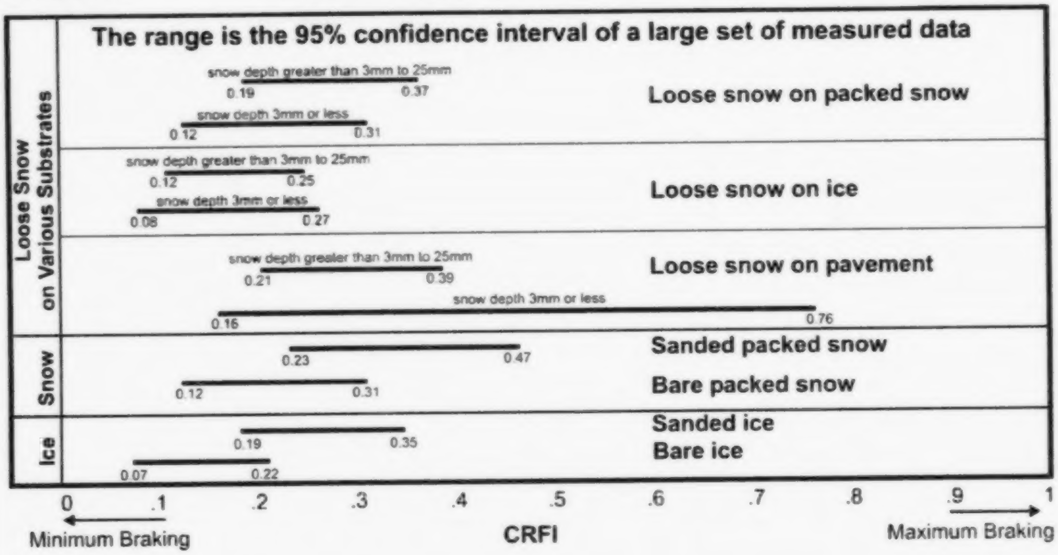


Table 4b **Expected Minimum and Maximum CRFIs for Various Surfaces**

Surface	Lower CRFI Limit	Upper CRFI Limit
Bare Ice	No Limit	0.3
Bare Packed Snow	0.1	0.4
Sanded Ice	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Ice: Depth - 3mm or Less	No Limit	0.4
Loose Snow on Ice: Depth - 3 to 25 mm	No Limit	0.4
Loose Snow on Packed Snow: Depth - 3mm or Less	0.1	0.4
Loose Snow on Packed Snow: Depth - 3 to 25 mm	0.1	0.4

Figure 5.1: Suggested Insert for the AIP

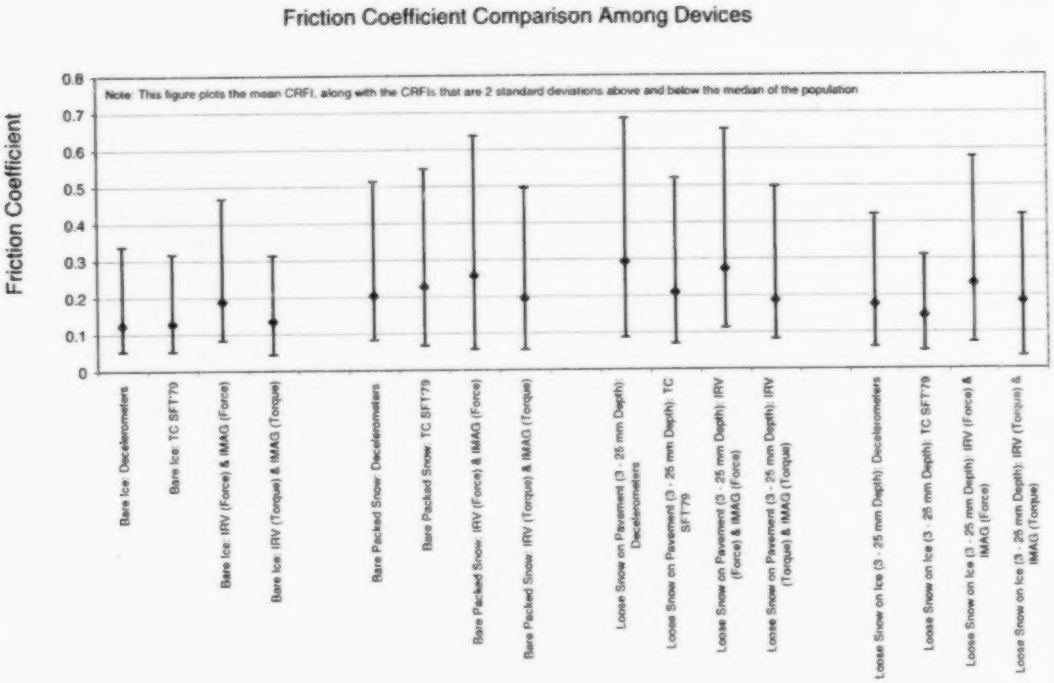


Figure 5.2: Friction Coefficient Comparison Among Devices

REFERENCES

[1] Comfort, G., and Trott, B., 2004, Joint Winter Runway Friction Test Program Database Manual, prepared by BMT Fleet Technology Ltd for the Transportation Development Centre on behalf of Aerodrome Safety Branch of Civil Aviation, Transport Canada.

[2] Comfort, G., 2003, Effect of Surface Conditions on the Friction Coefficients Measured on Winter Surfaces, Transport Canada report, TP 14220E.

[3] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP 13980E.

[4] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP 14176E.

[5] AIP, 2002, Aeronautical Information Publication, Air 1-15, Table 4, TP 2300.

[6] Comfort, G., and Gong, Y., 1998, Analysis of the Friction Factors Measured by the Ground Vehicles at the 1998 North Bay Trials, Transport Canada report, TP 13366E.

APPENDIX A

RAW DATA USED FOR THE ANALYSES

Contents:

Appendix A.1	ERD data
Appendix A.2	TC SFT data
Appendix A.3	IRV data
Appendix A.4	IRV and IMAG data combined

APPENDIX A.1

ERD DATA

Notes to Appendix A.1:

1. Data from the main Joint Winter Runway Friction Measurement Program (JWRFMP) [1] were combined with data from individual test programs in 2002 and 2003 ([2], [3]) to produce the data tabulated in this appendix.
2. Legend for Devices (first column of tables):
    a. ERD – Electronic Recording Decelerometer – may be either the Mk II or MK III
    b. ERD MK II – ERD model MK II
    c. ERD MK III – ERD model MK III
    d. Bowmonk – model # as indicated
    e. Tapley – model # as indicated

References:

[1] Comfort, G., and Trott, B., 2004, Joint Winter Runway Friction Measurement Program Database Manual, BMT Fleet Technology Ltd. report 5740, submitted to Transport Canada – TP # to come.

[2] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP 13980E.

[3] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP 14176E.

Bare Ice

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ
				(km/h)	(°C)	
ERD	North Bay	1996	96.25.4	50		0.210
ERD	North Bay	1996	96.17.1	40	-4	0.200
ERD	North Bay	1996	96.20.4	50		0.120
ERD	North Bay	1996	96.25.4	50		0.210
ERD	North Bay	1996	96.67.3	50	-9.5	0.170
ERD	North Bay	1996	96.68.2	50	-6.5	0.210
ERD	North Bay	1997	97.22.1	50	0.3	0.110
ERD	North Bay	1997	97.24.2	50	-10.6	0.210
ERD	North Bay	1997	97.27.2	50	-15.3	0.150
ERD	North Bay	1997	97.56.2	50		0.130
ERD	North Bay	1997	97.55.3	50	-10.5	0.150
ERD	North Bay	1997	97.57.4A	50		0.170
ERD	North Bay	1998	98.35.1A	50	-13.9	0.100
ERD	North Bay	1998	98.35.1B	50	-13	0.120
ERD	North Bay	1998	98.35.2	50	-7.5	0.110
ERD	North Bay	1998	98.35.2	50	-7.5	0.110
ERD	Norway	1998	98.68.2	50		0.150
ERD	Norway	1998	98.69.1	40	-8	0.110
ERD	Norway	1998	98.69.1	40	-8	0.110
ERD	Norway	1998	98.69.4	50	-1.5	0.090
ERD	Norway	1998	98.72.1A.1	40	-4	0.080
ERD	Norway	1998	98.72.1C.1	40	0	0.080
ERD	North Bay	1999	99.20.1A	40	-4.4	0.140
ERD	North Bay	1999	99.20.1A	40	-4.9	0.130
ERD	North Bay	1999	99.20.1A	40	-3.4	0.100
ERD	North Bay	1999	99.20.1A	40	-3.4	0.100
ERD	North Bay	1999	99.20.1A	50	-5.4	0.130
ERD	North Bay	1999	99.20.1A	50	-6.7	0.190
ERD	North Bay	1999	99.20.1A	50	-4.5	0.140
ERD	North Bay	1999	99.20.1A	50	-3.6	0.120
ERD	North Bay	1999	99.20.1A	65	-7	0.210
ERD	North Bay	1999	99.20.1A	65	-5.4	0.150
ERD	North Bay	1999	99.20.1A	65	-4.8	0.160
ERD	North Bay	1999	99.20.1A	65	-4.8	0.130
ERD	North Bay	1999	99.20.1A	80	-4.9	0.180
ERD	North Bay	1999	99.20.1A	80	-3.4	0.120
ERD	North Bay	1999	99.25.1	40	-3.6	0.095
ERD	North Bay	1999	99.25.1	40	-3.4	0.090
ERD	North Bay	1999	99.25.1	40	-1.4	0.085
ERD	North Bay	1999	99.25.1	40	-2	0.085
ERD	North Bay	1999	99.25.1	50	-4.1	0.095
ERD	North Bay	1999	99.25.1	50	-3.5	0.095
ERD	North Bay	1999	99.25.1	50	-2.6	0.085
ERD	North Bay	1999	99.25.1	50	-2.4	0.085

ERD	North Bay	1999	99.25.1	65	-5.1	0.095
ERD	North Bay	1999	99.25.1	65	-4	0.100
ERD	North Bay	1999	99.25.1	65	-3.4	0.090
ERD	North Bay	1999	99.25.1	65	-2.7	0.095
ERD	North Bay	1999	99.26.1	40	-4	0.105
ERD	North Bay	1999	99.26.1	40	-3.8	0.095
ERD	North Bay	1999	99.26.1	40	-3.5	0.095
ERD	North Bay	1999	99.26.1	40	-3	0.095
ERD	North Bay	1999	99.26.1	50	-4	0.110
ERD	North Bay	1999	99.26.1	50	-3.4	0.105
ERD	North Bay	1999	99.26.1	50	-3.3	0.100
ERD	North Bay	1999	99.26.1	50	-3.3	0.100
ERD	North Bay	1999	99.26.1	65	-4	0.150
ERD	North Bay	1999	99.26.1	65	-4	0.130
ERD	North Bay	1999	99.26.1	65	-3.6	0.110
ERD	North Bay	1999	99.26.1	65	-3.5	0.120
ERD	North Bay	1999	99.29.3	50		0.310
ERD	North Bay	1999	99.29.4	50		0.280
ERD	North Bay	1999	99.29.5	50		0.290
ERD	Norway	1999	99.61.1	35	-1	0.190
ERD	Norway	1999	99.61.1	35	-0.6	0.170
ERD	Norway	1999	99.61.1	35	-0.3	0.140
ERD	Norway	1999	99.61.1	50	-0.9	0.160
ERD	Norway	1999	99.61.1	50	-0.6	0.140
ERD	Norway	1999	99.61.1	50	-0.4	0.110
ERD	Norway	1999	99.61.1	65	-0.6	0.150
ERD	Norway	1999	99.61.1	65	-0.2	0.140
ERD	Norway	1999	99.61.1	65	-0.2	0.170
ERD	North Bay	2000	00.18.13	50		0.110
ERD	North Bay	2000	00.18.13	50		0.130
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ERD	North Bay	2000	00.20.3	50		0.140
ERD	North Bay	2000	00.20.3	50		0.130
ERD	North Bay	2000	00.20.3	50		0.130
ERD	North Bay	2000	00.20.3	50		0.130
ERD	North Bay	2000	00.20.3	50		0.130
ERD	North Bay	2000	00.20.3	50		0.120
ERD	North Bay	2000	00.20.3	50		0.120
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ERD	North Bay	2000	00.24.3B	50	-7.7	0.090
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ERD	North Bay	2000	00.25.6B	50		0.090
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ERD	North Bay	2000	00.25.7B	50		0.120
ERD	North Bay	2000	00.25.7B	50		0.110

ERD	North Bay	2001	01.23.1	50	-2.1	0.220
ERD	North Bay	2001	01.23.1	50	-2	0.170
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ERD	North Bay	2001	01.24.4	50	-2.9	0.150
ERD	North Bay	2001	01.24.4	50	-2.9	0.170
ERD	North Bay	2001	01.25.5	50	-4.7	0.100
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ERD	North Bay	2001	01.25.5	50	-4.7	0.090
ERD	North Bay	2001	01.25.5	50	-4.7	0.090
ERD	North Bay	2001	01.25.5	50	-4.7	0.100
ERD	North Bay	2001	01.25.5	50	-4.7	0.090
ERD	North Bay	2001	01.25.5	50	-4.7	0.080
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ERD	North Bay	2001	01.26.4	50	-1.9	0.080
ERD	North Bay	2001	01.26.4	50	-2	0.070
ERD	North Bay	2001	01.26.4	50	-2	0.070
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ERD	North Bay	2001	01.27.2	50	-5	0.060
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ERD	Munich	2001	01.59.1	50	-2	0.090
ERD	Munich	2001	01.59.1	50	-1.9	0.080
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ERD	Munich	2001	01.59.1	50	-1.4	0.080
ERD	Munich	2001	01.60.1	50	-0.2	0.100
ERD	Munich	2001	01.60.1	50	0	0.160
ERD	Munich	2001	01.60.3	50	-1.5	0.090
ERD	Munich	2001	01.60.3	50	-0.6	0.090
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ERD	Munich	2001	01.60.3	50	-1.5	0.100
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ERD	North Bay	2001	01.81.1	50		0.110
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ERD	North Bay	2002	02.35.3	50	-7	0.080
ERD	North Bay	2002	02.35.3	50	-7	0.090
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ERD	North Bay	2002	02.35.5	50	-9	0.100
ERD	North Bay	2002	02.35.5	50	-9	0.100
ERD	North Bay	2002	02.35.5	50	-10	0.100
ERD	North Bay	2002	02.35.5	50	-11	0.100
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ERD	North Bay	2002	02.38.3	50	-0.1	0.170
ERD	North Bay	2002	02.38.3	50	-0.1	0.170
ERD	North Bay	2002	02.38.3	50	-0.1	0.140

ERD	North Bay	2002	02.38.3	50	0	0.180
ERD	North Bay	2002	02.38.3	50	0	0.220
ERD	North Bay	2002	02.39.1	50	-10.0	0.280
ERD	North Bay	2002	02.39.1	50	-9.7	0.260
ERD	North Bay	2002	02.39.1	50	-9.5	0.290
ERD	North Bay	2002	02.39.1	50	-9.4	0.250
ERD	North Bay	2002	02.39.1	50	-9.3	0.290
ERD Mk III	North Bay	2002	n/a	40	-5.9	0.140
ERD Mk II	North Bay	2002	n/a	40	-5.9	0.140
ERD Mk III	North Bay	2002	n/a	40	-5.0	0.140
ERD Mk II	North Bay	2002	n/a	40	-5.0	0.140
ERD Mk III	North Bay	2002	n/a	40	-9.0	0.130
ERD Mk II	North Bay	2002	n/a	40	-9.0	0.130
Bowmonk AIP2	North Bay	2002	n/a	30	-9.0	0.170
Tapley BR 500	North Bay	2002	n/a	30	-9.0	0.190
ERD Mk III	North Bay	2002	n/a	40	-4.9	0.100
ERD Mk II	North Bay	2002	n/a	40	-4.9	0.110
ERD Mk III	North Bay	2002	n/a	30	-8.0	0.120
ERD Mk II	North Bay	2002	n/a	30	-8.0	0.120
Bowmonk AIP2	North Bay	2002	n/a	30	-8.0	0.140
Tapley BR 500	North Bay	2002	n/a	30	-8.0	0.190
ERD Mk III	North Bay	2002	n/a	40	-5.9	0.090
ERD Mk II	North Bay	2002	n/a	40	-5.9	0.090
ERD Mk III	North Bay	2002	n/a	40	-5.0	0.150
ERD Mk II	North Bay	2002	n/a	40	-5.0	0.160
ERD Mk III	North Bay	2002	n/a	30	-7.5	0.150
ERD Mk II	North Bay	2002	n/a	30	-7.5	0.150
Bowmonk AIP2	North Bay	2002	n/a	30	-7.5	0.190
Tapley BR 500	North Bay	2002	n/a	30	-7.5	0.240
ERD Mk III	North Bay	2002	n/a	40	-4.8	0.090
ERD Mk II	North Bay	2002	n/a	40	-4.8	0.080
ERD Mk III	North Bay	2002	n/a	30	-8.0	0.110
ERD Mk II	North Bay	2002	n/a	30	-8.0	0.100
Bowmonk AIP2	North Bay	2002	n/a	30	-8.0	0.120
Tapley BR 500	North Bay	2002	n/a	30	-8.0	0.160
ERD Mk III	North Bay	2002	n/a	40	-5.9	0.120
ERD Mk II	North Bay	2002	n/a	40	-5.9	0.120
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.100
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.100
ERD Mk III	North Bay	2002	n/a	40	-2.0	0.130
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.070
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.060
ERD Mk III	North Bay	2002	n/a	40	-5.9	0.140
ERD Mk II	North Bay	2002	n/a	40	-5.9	0.150
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.090
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.100
ERD Mk III	North Bay	2003	n/a	50	-17.0	0.123
ERD Mk II	North Bay	2003	n/a	50	-17.0	0.108

ERD Mk III	North Bay	2003	n/a	50	-17	0.120
ERD Mk II	North Bay	2003	n/a	50	-17	0.106
ERD Mk III	North Bay	2003	n/a	50	-17	0.120
ERD Mk II	North Bay	2003	n/a	50	-17	0.112
ERD Mk III	North Bay	2003	n/a	50	-17	0.119
ERD Mk II	North Bay	2003	n/a	50	-17	0.103
ERD Mk III	North Bay	2003	n/a	50	-17	0.112
ERD Mk II	North Bay	2003	n/a	50	-17	0.106
ERD Mk III	North Bay	2003	n/a	50	-17	0.100
ERD Mk II	North Bay	2003	n/a	50	-17	0.091
ERD Mk III	North Bay	2003	n/a	50	-15	0.129
ERD Mk II	North Bay	2003	n/a	50	-15	0.125
Bowmonk AFM2	North Bay	2003	n/a	50	-15	0.140
Tapley BR 500	North Bay	2003	n/a	50	-15	0.182
ERD Mk III	North Bay	2003	n/a	50	-15	0.131
ERD Mk II	North Bay	2003	n/a	50	-15	0.121
ERD Mk III	North Bay	2003	n/a	50	-15	0.129
ERD	North Bay	2003	n/a	50	-15	0.108
ERD Mk II	North Bay	2003	n/a	50	-15	0.127
ERD Mk III	North Bay	2003	n/a	50	-15	0.110
ERD Mk II	North Bay	2003	n/a	50	-15	0.100
ERD Mk III	North Bay	2003	n/a	50	-15	0.116
ERD Mk II	North Bay	2003	n/a	50	-15	0.107
ERD Mk II	Various	2003	n/a	50	-23.2	0.100
ERD Mk II	Various	2003	n/a	50	-23.2	0.120
ERD Mk II	Various	2003	n/a	50	-23.2	0.090
ERD Mk II	Various	2003	n/a	50	-23.2	0.120
ERD Mk II	Various	2003	n/a	50	-16	0.110
ERD Mk II	Various	2003	n/a	50	-16	0.130
ERD Mk II	Various	2003	n/a	50	-16	0.110
ERD Mk II	Various	2003	n/a	50	-16	0.140
ERD Mk II	Various	2003	n/a	50	-9.4	0.180
ERD Mk II	Various	2003	n/a	50	-9.4	0.160
ERD Mk II	Various	2003	n/a	50	-9.9	0.180
ERD Mk II	Various	2003	n/a	50	-9.9	0.200
ERD Mk II	Various	2003	n/a	50	-12	0.160
ERD Mk II	Various	2003	n/a	50	-12	0.170
ERD Mk II	Various	2003	n/a	50	-12	0.160
ERD Mk II	Various	2003	n/a	50	-12	0.150
ERD Mk II	Various	2003	n/a	50	-17.6	0.470
ERD Mk II	Various	2003	n/a	50	-15.6	0.400
ERD Mk II	Various	2003	n/a	50	-15.6	0.390
ERD Mk II	Various	2003	n/a	50	-15.6	0.330

Bare Packed Snow

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ
				(km/h)	(°C)	
ERD	North Bay	1996	96.24.6	50		0.250
ERD	North Bay	1996	96.24.8	50		0.290
ERD	North Bay	1996	96.25.1	50		0.280
ERD	North Bay	1996	96.25.3	50		0.280
ERD	North Bay	1996	96.25.3	50		0.260
ERD	North Bay	1996	96.66.1	50	-13.0	0.330
ERD	North Bay	1997	97.21.2	50	-12.9	0.250
ERD	North Bay	1997	97.29.1	50	-20.0	0.290
ERD	North Bay	1997	97.29.2	50	-20.0	0.290
ERD	North Bay	1997	97.29.4	50	-16.0	0.280
ERD	North Bay	1997	97.29.5	50	-16.0	0.290
ERD	North Bay	1997	97.59.5	50	-3.0	0.210
ERD	North Bay	1997	97.62.4	50	-2.5	0.340
ERD	North Bay	1997	97.63.2	50	-2.0	0.270
ERD	North Bay	1997	97.64.3	50		0.350
ERD	North Bay	1998	98.31.3A	50		0.220
ERD	North Bay	1998	98.44.1A	50		0.240
ERD	North Bay	1998	98.44.1A	50		0.250
ERD	North Bay	1998	98.44.1B	50		0.250
ERD	North Bay	1998	98.44.1B	50		0.240
ERD	North Bay	1998	98.45.1A	50		0.240
ERD	North Bay	1998	98.45.1A	50		0.220
ERD	North Bay	1998	98.45.1B	50		0.210
ERD	North Bay	1998	98.46.1A	50		0.200
ERD	North Bay	1998	98.46.1B	50		0.200
ERD	Norway	1998	98.68.1	50	-6.9	0.280
ERD	Norway	1998	98.68.1	50	-6.9	0.260
ERD	Norway	1998	98.69.2	50	-12.5	0.240
ERD	Norway	1998	98.69.2	50	-12.5	0.220
ERD	Norway	1998	98.69.3	50	-7.7	0.220
ERD	Norway	1998	98.69.3	50	-7.7	0.200
ERD	Norway	1998	98.69.5	50	-7.7	0.190
ERD	Norway	1998	98.69.5	50	-7.7	0.200
ERD	Norway	1998	98.70.2A	50	-7.8	0.200
ERD	Norway	1998	98.70.2C	50	-6.4	0.200
ERD	Norway	1998	98.72.2A.1	50	-4.9	0.230
ERD	North Bay	1999	99.22.1	40		0.200
ERD	North Bay	1999	99.22.1	40		0.140
ERD	North Bay	1999	99.22.1	40		0.100
ERD	North Bay	1999	99.22.1	40		0.210
ERD	North Bay	1999	99.22.1	50		0.220
ERD	North Bay	1999	99.22.1	50		0.190
ERD	North Bay	1999	99.22.1	50		0.110
ERD	North Bay	1999	99.22.1	50		0.200

ERD	North Bay	1999	99.22.1	65		0.240
ERD	North Bay	1999	99.22.1	65		0.210
ERD	North Bay	1999	99.22.1	65		0.140
ERD	North Bay	1999	99.22.1	65		0.140
ERD	Sawyer Field	1999	99.32.2A	50		0.360
ERD	Sawyer Field	1999	99.34.1	40		0.300
ERD	Sawyer Field	1999	99.34.1	40		0.260
ERD	Sawyer Field	1999	99.34.1	50		0.290
ERD	Sawyer Field	1999	99.34.1	40		0.260
ERD	Sawyer Field	1999	99.34.1	50		0.280
ERD	Sawyer Field	1999	99.34.1	50		0.270
ERD	Sawyer Field	1999	99.35.1	40	-8.0	0.190
ERD	Sawyer Field	1999	99.35.1	40	-8.5	0.150
ERD	Sawyer Field	1999	99.35.1	40	-9.0	0.150
ERD	Sawyer Field	1999	99.35.1	50	-8.0	0.180
ERD	Sawyer Field	1999	99.35.1	50	-8.0	0.180
ERD	Sawyer Field	1999	99.35.1	50	-9.0	0.140
ERD	Sawyer Field	1999	99.35.1	50	-9.0	0.150
ERD	Sawyer Field	1999	99.35.1	65	-8.0	0.220
ERD	Sawyer Field	1999	99.35.1	65	-8.5	0.190
ERD	Sawyer Field	1999	99.35.1	65	-8.7	0.170
ERD	Sawyer Field	1999	99.35.1	65	-8.7	0.190
ERD	Sawyer Field	1999	99.35.2	40	-8.2	0.150
ERD	Sawyer Field	1999	99.35.2	40	-8.2	0.160
ERD	Sawyer Field	1999	99.35.2	40	-8.9	0.130
ERD	Sawyer Field	1999	99.35.2	40	-8.9	0.130
ERD	Sawyer Field	1999	99.35.2	50	-7.8	0.180
ERD	Sawyer Field	1999	99.35.2	50	-7.8	0.140
ERD	Sawyer Field	1999	99.35.2	65	-7.7	0.240
ERD	Sawyer Field	1999	99.35.2	65	-7.7	0.210
ERD	Sawyer Field	1999	99.35.2	65	-7.8	0.160
ERD	Sawyer Field	1999	99.35.4	50	-11.0	0.350
ERD	Sawyer Field	1999	99.35.5	50	-8.4	0.360
ERD	Sawyer Field	1999	99.36.1A	40	-5.5	0.210
ERD	Sawyer Field	1999	99.36.1A	50	-5.5	0.200
ERD	Sawyer Field	1999	99.36.1A	65	-6.0	0.240
ERD	Sawyer Field	1999	99.37.3	50		0.290
ERD	Sawyer Field	1999	99.37.4	50		0.330
ERD	Sawyer Field	1999	99.38.1	50		0.290
ERD	Sawyer Field	1999	99.38.2	40		0.260
ERD	Sawyer Field	1999	99.38.2	50		0.260
ERD	Sawyer Field	1999	99.38.2	65		0.260
ERD	Norway	1999	99.61.2	65	-1.5	0.240
ERD	Norway	1999	99.61.2	40	-1.0	0.250
ERD	Norway	1999	99.61.2	40	-2.0	0.270
ERD	Norway	1999	99.61.2	65	-1.0	0.280
ERD	Norway	1999	99.61.2	50	-1.5	0.260
ERD	Norway	1999	99.61.2	50	-1.0	0.240

ERD	North Bay	2001	01.26.2	50	-7.6	0.150
ERD	North Bay	2001	01.26.2	50	-7.6	0.200
ERD	North Bay	2001	01.26.2	50	-7.6	0.180
ERD	North Bay	2001	01.26.2	50	-7.6	0.180
ERD	North Bay	2001	01.26.2	50	-7.6	0.170
ERD	North Bay	2001	01.26.5	50	-3.9	0.130
ERD	North Bay	2001	01.26.5	50	-3.9	0.150
ERD	North Bay	2001	01.26.5	50	-3.9	0.160
ERD	North Bay	2001	01.27.1	50	-10.0	0.150
ERD	North Bay	2001	01.27.1	50	-10.0	0.150
ERD	North Bay	2001	01.27.1	50	-10.0	0.150
ERD	North Bay	2001	01.27.1	50	-10.0	0.120
ERD	North Bay	2001	01.27.1	50	-10.0	0.140
ERD	North Bay	2001	01.27.1	50	-10.0	0.120
ERD	North Bay	2001	01.27.1	50	-10.0	0.110
ERD	North Bay	2001	01.27.1	50	-10.0	0.120
ERD	North Bay	2001	01.27.1	50	-10.0	0.110
ERD	North Bay	2001	01.27.1	50	-10.0	0.110
ERD	North Bay	2001	01.27.1	50	-10.0	0.130
ERD	North Bay	2002	02.35.6	50	-7.7	0.200
ERD	North Bay	2002	02.35.2	50	-6.0	0.170
ERD	North Bay	2002	02.35.2	50	-6.0	0.180
ERD	North Bay	2002	02.35.2	50	-6.0	0.130
ERD	North Bay	2002	02.35.2	50	-6.0	0.160
ERD	North Bay	2002	02.35.2	50	-6.0	0.160
ERD	North Bay	2002	02.35.4	50	-5.0	0.170
ERD	North Bay	2002	02.35.4	50	-5.0	0.140
ERD	North Bay	2002	02.35.4	50	-5.0	0.130
ERD	North Bay	2002	02.35.4	50	-5.0	0.140
ERD	North Bay	2002	02.35.4	50	-5.0	0.140
ERD	North Bay	2002	02.35.4	50	-5.0	0.130
ERD	North Bay	2002	02.35.4	50	-5.0	0.120
ERD	North Bay	2002	02.35.6	50	-12.5	0.170
ERD	North Bay	2002	02.35.6	50	-12.5	0.160
ERD	North Bay	2002	02.35.6	50	-12.5	0.170
ERD	North Bay	2002	02.35.6	50	-12.5	0.190
ERD	North Bay	2002	02.35.6	50	-12.5	0.180
ERD	North Bay	2002	02.35.6	50	-12.5	0.150
ERD	North Bay	2002	02.36.7	50	-6.4	0.140
ERD	North Bay	2002	02.36.7	50	-6.4	0.150
ERD	North Bay	2002	02.36.7	50	-6.4	0.140
ERD	North Bay	2002	02.36.7	50	-6.4	0.160
ERD	North Bay	2002	02.36.7	50	-6.4	0.130
ERD	North Bay	2002	02.36.7	50	-6.4	0.150
ERD	North Bay	2002	02.36.7	50	-6.4	0.150
ERD	North Bay	2002	02.36.8	50	-9.5	0.170
ERD	North Bay	2002	02.36.8	50	-9.5	0.220
ERD	North Bay	2002	02.36.8	50	-9.5	0.210

ERD	North Bay	2002	02.36.8	50	-9.5	0.190
ERD	North Bay	2002	02.36.9	50	-9.4	0.170
ERD	North Bay	2002	02.36.9	50	-9.4	0.180
ERD	North Bay	2002	02.36.9	50	-9.4	0.180
ERD	North Bay	2002	02.36.9	50	-9.4	0.160
ERD	North Bay	2002	02.37.2	50	-2.2	0.180
ERD	North Bay	2002	02.37.2	50	-2.2	0.180
ERD	North Bay	2002	02.37.2	50	-2.2	0.160
ERD	North Bay	2002	02.37.2	50	-2.5	0.180
ERD	North Bay	2002	02.37.2	50	-2.5	0.180
ERD	North Bay	2002	02.37.2	50	-2.5	0.180
ERD	North Bay	2002	02.38.1	50	-2.2	0.170
ERD	North Bay	2002	02.38.1	50	-2.2	0.170
ERD	North Bay	2002	02.38.1	50	-2.2	0.170
ERD	North Bay	2002	02.38.1	50	-2.2	0.170
ERD	North Bay	2002	02.38.1	50	-2.2	0.150
ERD	North Bay	2002	02.38.1	50	-2.2	0.160
ERD	North Bay	2002	02.38.4	50	-0.3	0.260
ERD	North Bay	2002	02.38.4	50	-0.3	0.300
ERD	North Bay	2002	02.38.4	50	-0.3	0.270
ERD	North Bay	2002	02.38.4	50	-0.3	0.270
ERD	North Bay	2002	02.38.2	50	-2.6	0.170
ERD	North Bay	2002	02.38.2	50	-2.6	0.140
ERD	North Bay	2002	02.38.2	50	-2.6	0.140
ERD	North Bay	2002	02.38.2	50	-2.6	0.140
ERD	North Bay	2002	02.38.2	50	-2.6	0.170
ERD	North Bay	2002	02.38.2	50	-2.6	0.120
ERD	North Bay	2002	02.39.3	50	-10.8	0.160
ERD	North Bay	2002	02.39.3	50	-10.8	0.180
ERD	North Bay	2002	02.39.3	50	-10.5	0.150
ERD	North Bay	2002	02.39.3	50	-10.5	0.150
ERD	North Bay	2002	02.39.3	50	-10.5	0.120
ERD	North Bay	2002	02.39.3	50	-10.2	0.150
ERD	North Bay	2002	02.39.4	50	-10.2	0.220
ERD	North Bay	2002	02.39.4	50	-10.5	0.200
ERD	North Bay	2002	02.39.4	50	-10.5	0.160
ERD	North Bay	2002	02.39.4	50	-10.5	0.150
ERD	North Bay	2002	02.39.4	50	-10.5	0.120
ERD	North Bay	2002	02.39.4	50	-10.5	0.170
ERD Mk III	North Bay	2002	n/a	40	-5.7	0.230
ERD MK III	North Bay	2002	n/a	40	-6	0.240
ERD Mk II	North Bay	2002	n/a	40	-6	0.250
ERD MK III	North Bay	2002	n/a	40	-4.50	0.260
ERD Mk II	North Bay	2002	n/a	40	-4.50	0.270
ERD MK III	North Bay	2002	n/a	40	-6	0.290
ERD Mk II	North Bay	2002	n/a	40	-6	0.290
ERD MK III	North Bay	2002	n/a	40	-5.7	0.170
ERD MK III	North Bay	2002	n/a	40	-6	0.280

ERD Mk II	Various	2003	n/a	50	-23.5	0.33
ERD Mk II	Various	2003	n/a	50	-23.5	0.32
ERD Mk II	Various	2003	n/a	50	-23.5	0.31
ERD Mk II	Various	2003	n/a	50	-23.5	0.33
ERD Mk II	Various	2003	n/a	50	-15.9	0.27
ERD Mk II	Various	2003	n/a	50	-15.9	0.28
ERD Mk II	Various	2003	n/a	50	-15.9	0.24
ERD Mk II	Various	2003	n/a	50	-15.9	0.24
ERD Mk II	Various	2003	n/a	50	-23.7	0.27
ERD Mk III	Various	2003	n/a	50	-23.7	0.22
ERD Mk II	Various	2003	n/a	50	-23.7	0.27
ERD Mk III	Various	2003	n/a	50	-23.7	0.25
ERD Mk II	Various	2003	n/a	50	-24.4	0.15
ERD Mk III	Various	2003	n/a	50	-24.4	0.12
ERD Mk II	Various	2003	n/a	50	-24.4	0.13
ERD Mk III	Various	2003	n/a	50	-24.4	0.09
ERD Mk II	Various	2003	n/a	50	-18.2	0.21
ERD Mk III	Various	2003	n/a	50	-18.2	0.12
ERD Mk II	Various	2003	n/a	50	-18.2	0.2
ERD Mk III	Various	2003	n/a	50	-18.2	0.11
ERD Mk II	Various	2003	n/a	50	-19	0.21
ERD Mk III	Various	2003	n/a	50	-19	0.21
ERD Mk II	Various	2003	n/a	50	-19	0.21
ERD Mk III	Various	2003	n/a	50	-19	0.19

Sanded Ice

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ
ERD	North Bay	1996	96.20.5	50		0.210
ERD	North Bay	1996	96.20.6	50		0.220
ERD	North Bay	1996	96.25.6	50		0.240
ERD	North Bay	1996	96.25.6	50		0.250
ERD	North Bay	1996	96.25.8	50		0.270
ERD	North Bay	1996	96.62.2	50	-5.0	0.160
ERD	North Bay	1996	96.63.1	50	-9.3	0.290
ERD	North Bay	1996	96.64.1	50	-14.5	0.300
ERD	North Bay	1997	97.57.4B	50		0.200
ERD	North Bay	1997	97.57.4C	50		0.190
ERD	Norway	1998	98.72.1A.2	40		0.340
ERD	Norway	1998	98.72.1C.2	40	0.0	0.230
ERD Mk III	North Bay	2002	n/a	40	-11	0.250
ERD Mk II	North Bay	2002	n/a	40	-11	0.240
ERD Mk III	North Bay	2002	n/a	40	-11	0.220
ERD Mk II	North Bay	2002	n/a	40	-11	0.230
ERD Mk III	North Bay	2002	n/a	40	-10	0.250
ERD Mk II	North Bay	2002	n/a	40	-10	0.260
ERD Mk III	North Bay	2002	n/a	40	-11	0.220
ERD Mk II	North Bay	2002	n/a	40	-11	0.220
ERD Mk III	North Bay	2002	n/a	40	-11	0.200
ERD Mk II	North Bay	2002	n/a	40	-11	0.200
ERD Mk III	North Bay	2002	n/a	40	-11	0.250
ERD Mk II	North Bay	2002	n/a	40	-11	0.250
ERD Mk III	North Bay	2002	n/a	40	-11	0.210
ERD Mk II	North Bay	2002	n/a	40	-11	0.220
ERD Mk II	Various	2003	n/a	50	-6.9	0.340
ERD Mk II	Various	2003	n/a	50	-6.9	0.380

Sanded Packed Snow

Device	Site	Year	Test no.	Speed (km/h)	Temp. (^{o}C)	Avg. μ
ERD Mk III	North Bay	2002	n/a	40	-11	0.320
ERD Mk II	North Bay	2002	n/a	40	-11	0.300
ERD Mk III	North Bay	2002	n/a	40	-11	0.300
ERD Mk II	North Bay	2002	n/a	40	-11	0.310
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.280
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.290
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.360
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.360
ERD Mk III	North Bay	2002	n/a	30	-8.00	0.290
ERD Mk II	North Bay	2002	n/a	30	-8.00	0.290
Bowmonk AIP2	North Bay	2002	n/a	30	-8.00	0.320
Tapley BR 500	North Bay	2002	n/a	30	-8.00	0.370
ERD Mk III	North Bay	2002	n/a	40	-11	0.320
ERD Mk II	North Bay	2002	n/a	40	-11	0.330
ERD Mk III	North Bay	2002	n/a	40	-11	0.300
ERD Mk II	North Bay	2002	n/a	40	-11	0.310
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.340
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.330
ERD Mk III	North Bay	2002	n/a	30	-8.00	0.360
ERD Mk II	North Bay	2002	n/a	30	-8.00	0.370
Bowmonk AIP2	North Bay	2002	n/a	30	-8.00	0.400
Tapley BR 500	North Bay	2002	n/a	30	-8.00	0.430
ERD Mk III	North Bay	2002	n/a	40	-11	0.310
ERD Mk II	North Bay	2002	n/a	40	-11	0.310
ERD Mk III	North Bay	2002	n/a	40	-4.50	0.350
ERD Mk II	North Bay	2002	n/a	40	-4.50	0.350
ERD Mk III	North Bay	2002	n/a	40	-11	0.250
ERD Mk II	North Bay	2002	n/a	40	-11	0.250
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.300
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.300
ERD Mk III	North Bay	2002	n/a	40	-11	0.330
ERD Mk II	North Bay	2002	n/a	40	-11	0.320
ERD Mk III	North Bay	2002	n/a	40	-4.5	0.390
ERD Mk II	North Bay	2002	n/a	40	-4.5	0.390
ERD Mk III	North Bay	2003	n/a	50	-14	0.375
ERD Mk II	North Bay	2003	n/a	50	-14	0.381
Bowmonk AFM2	North Bay	2003	n/a	50	-14	0.361
Tapley BR 500	North Bay	2003	n/a	50	-14	0.473
Mk III	North Bay	2003	n/a	50	-14	0.388
Mk II	North Bay	2003	n/a	50	-14	0.376
Bowmonk AFM2	North Bay	2003	n/a	50	-14	0.265
Tapley BR 500	North Bay	2003	n/a	50	-14	0.443
ERD Mk III	North Bay	2003	n/a	50	-14	0.421
ERD Mk II	North Bay	2003	n/a	50	-14	0.394

Bowmonk AFM2	North Bay	2003	n/a	50	-14	0.336
Tapley BR 500	North Bay	2003	n/a	50	-14	0.469
ERD Mk III	North Bay	2003	n/a	50	-14	0.465
ERD Mk II	North Bay	2003	n/a	50	-14	0.465
ERD Mk III	North Bay	2003	n/a	50	-14	0.474
ERD Mk II	North Bay	2003	n/a	50	-14	0.467
Bowmonk AFM2	North Bay	2003	n/a	50	-14	0.413
ERD Mk III	North Bay	2003	n/a	50	-14	0.427
ERD Mk II	North Bay	2003	n/a	50	-14	0.417
ERD Mk III	North Bay	2003	n/a	50	-14	0.438
ERD Mk II	North Bay	2003	n/a	50	-14	0.426
ERD Mk III	North Bay	2003	n/a	50	-14	0.463
ERD Mk II	North Bay	2003	n/a	50	-14	0.449
Bowmonk AFM2	North Bay	2003	n/a	50	-14	0.452
ERD Mk II	Various	2003	n/a	50	-21.9	0.310
ERD Mk III	Various	2003	n/a	50	-21.9	0.280
ERD Mk II	Various	2003	n/a	50	-21.9	0.310
ERD Mk III	Various	2003	n/a	50	-21.9	0.300
ERD Mk II	Various	2003	n/a	50	-20.7	0.300
ERD Mk III	Various	2003	n/a	50	-20.7	0.260
ERD Mk II	Various	2003	n/a	50	-20.7	0.290
ERD Mk III	Various	2003	n/a	50	-20.7	0.280
ERD Mk II	Various	2003	n/a	50	-17.2	0.230
ERD Mk III	Various	2003	n/a	50	-17.2	0.160
ERD Mk II	Various	2003	n/a	50	-17.2	0.210
ERD Mk III	Various	2003	n/a	50	-17.2	0.140

Loose Snow on Pavement <= 3 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ	Depth (mm)
ERD	Norway	1999	99.62.4	40	-2.0	0.170	1.5
ERD	Norway	1999	99.62.4	40	-2.0	0.140	1.5
ERD	Norway	1999	99.62.4	65	-2.0	0.190	1.5
ERD	Norway	1999	99.62.4	70	-2.0	0.200	1.5
ERD	Norway	1999	99.62.4	70	-2.0	0.190	1.5
ERD	Norway	1999	99.62.4	65	-2.0	0.160	1.5
ERD	North Bay	2001	01.22.2	50	-5.3	0.650	0.1
ERD Mk II	Various	2003	n/a	50	-22.6	0.55	1
ERD Mk II	Various	2003	n/a	50	-22.6	0.55	1
ERD Mk II	Various	2003	n/a	50	-22.6	0.57	1
ERD Mk II	Various	2003	n/a	50	-22.6	0.55	1
ERD Mk II	Various	2003	n/a	50	-14.9	0.43	1
ERD Mk II	Various	2003	n/a	50	-14.9	0.42	1
ERD Mk II	Various	2003	n/a	50	-14.9	0.42	1
ERD Mk II	Various	2003	n/a	50	-14.9	0.44	1
ERD Mk II	Various	2003	n/a	50	-5.6	0.36	1
ERD Mk III	Various	2003	n/a	50	-5.6	0.39	1
ERD Mk II	Various	2003	n/a	50	-5.6	0.35	1
ERD Mk III	Various	2003	n/a	50	-5.6	0.46	1
ERD Mk II	Various	2003	n/a	50	-12.2	0.7	1
ERD Mk II	Various	2003	n/a	50	-12.2	0.76	1
ERD Mk II	Various	2003	n/a	50	-12.2	0.72	1
ERD Mk II	Various	2003	n/a	50	-12.2	0.79	1
ERD Mk III	North Bay	2003	n/a	50	-21	0.299	3
ERD Mk II	North Bay	2003	n/a	50	-21	0.283	3
ERD Mk III	North Bay	2003	n/a	50	-21	0.313	3
ERD Mk II	North Bay	2003	n/a	50	-21	0.303	3
ERD Mk III	North Bay	2003	n/a	50	-21	0.254	3
ERD Mk II	North Bay	2003	n/a	50	-21	0.245	3
ERD Mk III	North Bay	2003	n/a	50	-21	0.290	3
ERD Mk II	North Bay	2003	n/a	50	-21	0.289	3
Bowmonk AFM2	North Bay	2003	n/a	50	-21	0.279	3
Tapley BR 500	North Bay	2003	n/a	50	-21	0.349	3
ERD Mk III	North Bay	2003	n/a	50	-21	0.243	3
ERD Mk II	North Bay	2003	n/a	50	-21	0.228	3
Bowmonk AFM2	North Bay	2003	n/a	50	-21	0.215	3
ERD Mk III	North Bay	2003	n/a	50	-21	0.316	3
Bowmonk AFM2	North Bay	2003	n/a	50	-21	0.326	3

Loose Snow on Pavement Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ	Depth (mm)
ERD	North Bay	1996	96.66.4	50	-9.5	0.390	6.5
ERD	North Bay	1996	96.66.8	50	-10.0	0.390	6
ERD	North Bay	1996	96.67.6	50	-7.0	0.390	8.5
ERD	North Bay	1996	96.67.10	50	-7.0	0.360	8.5
ERD	North Bay	1997	97.25.4	50	-8.6	0.200	25
ERD	North Bay	1997	97.28.1	50	-21.0	0.290	6
ERD	North Bay	1997	97.29.3	50		0.280	22
ERD	North Bay	1997	97.62.3	50		0.290	25
ERD	North Bay	1997	97.62.5	50	-4.2	0.350	13
ERD	North Bay	1997	97.62.6	50	-3.9	0.280	16
ERD Mk III	North Bay	2003	n/a	50	-13	0.272	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.263	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.257	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.249	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.243	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.229	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.242	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.223	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.213	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.205	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.302	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.309	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.298	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.293	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.283	6
ERD Mk III	North Bay	2003	n/a	50	-13	0.266	6
ERD Mk II	North Bay	2003	n/a	50	-13	0.253	6
ERD Mk III	North Bay	2003	n/a	50	-4	0.364	6
ERD Mk II	North Bay	2003	n/a	50	-4	0.362	6
ERD Mk III	North Bay	2003	n/a	50	-4	0.360	6
ERD Mk II	North Bay	2003	n/a	50	-4	0.348	6
ERD Mk III	North Bay	2003	n/a	50	-4	0.312	6
ERD Mk II	North Bay	2003	n/a	50	-4	0.314	6

Loose Snow on Ice <= 3 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ	Depth
				(km/h)	(°C)		
ERD	North Bay	2001	01.22.1	50	-6.3	0.210	2
ERD	North Bay	2001	01.22.1	50	-6.3	0.200	2
ERD	North Bay	2001	01.22.1	50	-6.3	0.210	2
ERD Mk II	Various	2003	n/a	50	-13.4	0.270	3
ERD Mk III	Various	2003	n/a	50	-13.4	0.240	3
ERD Mk II	Various	2003	n/a	50	-13.4	0.280	3
ERD Mk III	Various	2003	n/a	50	-13.4	0.260	3
ERD Mk II	Various	2003	n/a	50	-14.3	0.270	3
ERD Mk III	Various	2003	n/a	50	-14.3	0.270	3
ERD Mk II	Various	2003	n/a	50	-14.3	0.270	3
ERD Mk III	Various	2003	n/a	50	-14.3	0.270	3
ERD Mk II	Various	2003	n/a	50	-14.4	0.300	3
ERD Mk II	Various	2003	n/a	50	-14.4	0.230	3
ERD Mk II	Various	2003	n/a	50	-14.4	0.280	3
ERD Mk II	Various	2003	n/a	50	-14.4	0.240	3

Loose Snow on Ice Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	Depth
				(km/h)	(°C)		(mm)
ERD	North Bay	1997	97.28.5	50	-12.5	0.240	5
ERD	North Bay	1997	97.55.1	50	-20.2	0.220	25
ERD	North Bay	1997	97.55.1	50	-20.2	0.180	25
ERD	North Bay	1997	97.56.1	50	-15.6	0.240	10
ERD	North Bay	1997	97.56.5	50		0.200	16
ERD	North Bay	1999	99.19.2	40	-1.0	0.120	5
ERD	North Bay	1999	99.19.2	40	-1.0	0.120	5
ERD	North Bay	1999	99.19.2	40	-1.0	0.120	5
ERD	North Bay	1999	99.19.2	40	-1.0	0.095	5
ERD	North Bay	1999	99.19.2	50	-1.0	0.180	5
ERD	North Bay	1999	99.19.2	50	-1.0	0.167	5
ERD	North Bay	1999	99.19.2	50	-1.0	0.130	5
ERD	North Bay	1999	99.19.2	50	-1.0	0.115	5
ERD	North Bay	1999	99.19.2	65	-1.0	0.283	5
ERD	North Bay	1999	99.19.2	65	-1.0	0.237	5
ERD	North Bay	1999	99.19.2	65	-1.0	0.147	5
ERD	North Bay	1999	99.19.2	65	-1.0	0.137	5
ERD	North Bay	1999	99.20.1B	40	-8.0	0.180	5
ERD	North Bay	1999	99.20.1B	40	-8.0	0.160	5
ERD	North Bay	1999	99.20.1B	40	-5.0	0.140	5
ERD	North Bay	1999	99.20.1B	40	-5.0	0.145	5
ERD	North Bay	1999	99.20.1B	50	-7.0	0.185	5
ERD	North Bay	1999	99.20.1B	50	-8.0	0.165	5
ERD	North Bay	1999	99.20.1B	50	-6.0	0.150	5
ERD	North Bay	1999	99.20.1B	50	-5.0	0.160	5
ERD	North Bay	1999	99.20.1B	65	-7.0	0.215	5
ERD	North Bay	1999	99.20.1B	65	-7.0	0.170	5
ERD	North Bay	1999	99.20.1B	65	-5.0	0.175	5
ERD	North Bay	1999	99.20.1B	65	-6.0	0.150	5
ERD	North Bay	1999	99.20.1B	80	-5.0	0.170	5
ERD	North Bay	1999	99.20.1B	80	-6.0	0.180	5
ERD	Norway	1999	99.62.1	50	-3.7	0.160	10
ERD	Norway	1999	99.62.1	35	-3.7	0.170	10
ERD	Norway	1999	99.62.1	50	-3.7	0.150	10
ERD	Norway	1999	99.62.1	35	-3.7	0.160	10
ERD	Norway	1999	99.62.1	65	-3.7	0.180	10
ERD	North Bay	2001	01.24.1	50	-1.7	0.240	17
ERD	North Bay	2001	01.24.1	50	-1.7	0.220	17
ERD	North Bay	2001	01.24.1	50	-1.7	0.210	17
ERD Mk II	Various	2003	n/a	50	-5.6	0.190	12
ERD Mk III	Various	2003	n/a	50	-5.6	0.200	12
ERD Mk II	Various	2003	n/a	50	-5.6	0.180	12
ERD Mk III	Various	2003	n/a	50	-5.6	0.180	12

Loose Snow on Packed Snow <= 3 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (^{o}C)	Avg. μ	Depth (mm)
ERD Mk II	Various	2003	n/a	50	-13.6	0.350	3
ERD Mk III	Various	2003	n/a	50	-13.6	0.280	3
ERD Mk II	Various	2003	n/a	50	-13.6	0.310	3
ERD Mk III	Various	2003	n/a	50	-13.6	0.280	3

Loose Snow on Packed Snow Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. µ	Depth (mm)
ERD	North Bay	2001	01.32.1	50	-10.5	0.240	5
ERD	North Bay	2001	01.32.1	50	-10.5	0.200	5
ERD	North Bay	2001	01.32.1	50	-10.5	0.180	5
ERD	North Bay	2001	01.32.1	50	-10.5	0.190	5
ERD	North Bay	2001	01.32.1	50	-10.5	0.170	5
ERD	North Bay	2001	01.32.4	50	-6.3	0.240	6
ERD	North Bay	2001	01.32.4	50	-6.3	0.260	6
ERD	North Bay	2001	01.32.4	50	-6.3	0.270	6
ERD	North Bay	2001	01.32.4	50	-6.3	0.260	6
ERD MK III	North Bay	2002	n/a	30	-11.0	0.330	19
ERD Mk II	North Bay	2002	n/a	30	-11.0	0.330	19
Bowmonk AIP2	North Bay	2002	n/a	30	-11.0	0.330	19
Tapley BR 500	North Bay	2002	n/a	30	-11.0	0.370	19
ERD MK III	North Bay	2002	n/a	40	-6	0.220	25
ERD Mk III	North Bay	2003	n/a	50	-10	0.316	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.293	6
Bowmonk AFM2	North Bay	2003	n/a	50	-10	0.320	6
Tapley BR 500	North Bay	2003	n/a	50	-10	0.365	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.293	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.281	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.343	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.331	6
Bowmonk AFM2	North Bay	2003	n/a	50	-10	0.359	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.250	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.223	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.222	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.306	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.296	6
Bowmonk AFM2	North Bay	2003	n/a	50	-10	0.320	6
Tapley BR 500	North Bay	2003	n/a	50	-10	0.357	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.281	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.248	6
ERD Mk III	North Bay	2003	n/a	50	-10	0.247	6
ERD Mk II	North Bay	2003	n/a	50	-10	0.250	6
ERD Mk III	North Bay	2003	n/a	50	-9	0.256	6
ERD Mk II	North Bay	2003	n/a	50	-9	0.236	6
ERD Mk III	North Bay	2003	n/a	50	-9	0.246	6
ERD Mk II	North Bay	2003	n/a	50	-9	0.236	6
ERD Mk III	North Bay	2003	n/a	50	-9	0.219	6
ERD Mk II	North Bay	2003	n/a	50	-9	0.219	6
ERD Mk II	Various	2003	n/a	50	-12.9	0.300	4
ERD Mk III	Various	2003	n/a	50	-12.9	0.230	4
ERD Mk II	Various	2003	n/a	50	-12.9	0.280	4
ERD Mk III	Various	2003	n/a	50	-12.9	0.220	4

ERD Mk II	Various	2003	n/a	50	-17	0.300	4
ERD Mk III	Various	2003	n/a	50	-17	0.220	4
ERD Mk II	Various	2003	n/a	50	-17	0.300	4
ERD Mk III	Various	2003	n/a	50	-17	0.200	4
ERD Mk II	Various	2003	n/a	50	-15	0.280	4
ERD Mk III	Various	2003	n/a	50	-15	0.220	4
ERD Mk II	Various	2003	n/a	50	-5.6	0.200	12
ERD Mk III	Various	2003	n/a	50	-5.6	0.210	12
ERD Mk II	Various	2003	n/a	50	-5.6	0.200	12
ERD Mk III	Various	2003	n/a	50	-5.6	0.220	12

APPENDIX A.2

TC SFT'79 DATA

Bare Ice

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. µ
TC SFT	North Bay	1998	98.35.1A	40	-13.9	0.170
TC SFT	North Bay	1998	98.35.1A	42	-13.5	0.180
TC SFT	North Bay	1998	98.35.1A	51	-13	0.180
TC SFT	North Bay	1998	98.35.1A	51	-12.5	0.200
TC SFT	North Bay	1998	98.35.1A	64	-12	0.210
TC SFT	North Bay	1998	98.35.1A	67	-11.1	0.180
TC SFT	North Bay	1998	98.35.1B	43	-12.5	0.190
TC SFT	North Bay	1998	98.35.1B	41	-12.5	0.210
TC SFT	North Bay	1998	98.35.1B	51	-12.5	0.200
TC SFT	North Bay	1998	98.35.1B	52	-12	0.200
TC SFT	North Bay	1998	98.35.1B	69	-12	0.180
TC SFT	North Bay	1998	98.35.1B	69	-12	0.180
TC SFT	North Bay	1998	98.35.2	50	-7	0.140
TC SFT	North Bay	1998	98.35.2	50	-6.7	0.150
TC SFT	North Bay	1998	98.35.2	50	-6.5	0.140
TC SFT	North Bay	1998	98.35.2	52	-6.3	0.140
TC SFT	Norway	1998	98.69.1	45	-7.7	0.080
TC SFT	Norway	1998	98.69.1	54	-7.7	0.090
TC SFT	Norway	1998	98.69.4	49	-2	0.050
TC SFT	Norway	1998	98.69.4	50	-1.5	0.040
TC SFT	Norway	1998	98.72.1A.1	42	-2.5	0.050
TC SFT	Norway	1998	98.72.1A.1	45	-2.5	0.070
TC SFT	Norway	1998	98.72.1B.1	42	-2	0.100
TC SFT	Norway	1998	98.72.1B.1	52	-2	0.100
TC SFT	Norway	1998	98.72.1C.1	45	-0.2	0.080
TC SFT	Norway	1998	98.72.1C.1	49	-0.2	0.070
TC SFT	North Bay	1999	99.20.1A	41	-5	0.190
TC SFT	North Bay	1999	99.20.1A	41	-4.4	0.150
TC SFT	North Bay	1999	99.20.1A	41	-3.4	0.100
TC SFT	North Bay	1999	99.20.1A	40	-3.4	0.120
TC SFT	North Bay	1999	99.20.1A	51	-5.4	0.180
TC SFT	North Bay	1999	99.20.1A	51	-6.7	0.220
TC SFT	North Bay	1999	99.20.1A	51	-4	0.110
TC SFT	North Bay	1999	99.20.1A	50	-3.8	0.110
TC SFT	North Bay	1999	99.20.1A	66	-6	0.240
TC SFT	North Bay	1999	99.20.1A	64	-6	0.200
TC SFT	North Bay	1999	99.20.1A	64	-4.8	0.120
TC SFT	North Bay	1999	99.20.1A	64	-4.8	0.160
TC SFT	North Bay	1999	99.20.1A	80	-4.9	0.190
TC SFT	North Bay	1999	99.20.1A	80	-3.4	0.100
TC SFT	North Bay	1999	99.25.1	42	-3.6	0.130
TC SFT	North Bay	1999	99.25.1	41	-3.3	0.120
TC SFT	North Bay	1999	99.25.1	40	-1.5	0.100
TC SFT	North Bay	1999	99.25.1	40	-1.7	0.110

TC SFT	North Bay	1999	99.25.1	52	-4.2	0.130
TC SFT	North Bay	1999	99.25.1	50	-4.2	0.120
TC SFT	North Bay	1999	99.25.1	52	-2.7	0.100
TC SFT	North Bay	1999	99.25.1	53	-2.4	0.100
TC SFT	North Bay	1999	99.25.1	66	-5.1	0.130
TC SFT	North Bay	1999	99.25.1	65	-5.1	0.130
TC SFT	North Bay	1999	99.25.1	66	-3.4	0.100
TC SFT	North Bay	1999	99.25.1	64	-2.9	0.110
TC SFT	North Bay	1999	99.26.1	40	-4.1	0.170
TC SFT	North Bay	1999	99.26.1	39	-3.8	0.160
TC SFT	North Bay	1999	99.26.1	41	-3.6	0.140
TC SFT	North Bay	1999	99.26.1	40	-3.4	0.130
TC SFT	North Bay	1999	99.26.1	52	-4.2	0.190
TC SFT	North Bay	1999	99.26.1	52	-4.2	0.160
TC SFT	North Bay	1999	99.26.1	50	-3.4	0.140
TC SFT	North Bay	1999	99.26.1	49	-3.4	0.130
TC SFT	North Bay	1999	99.26.1	63	-4	0.210
TC SFT	North Bay	1999	99.26.1	64	-4.2	0.170
TC SFT	North Bay	1999	99.26.1	65	-3.8	0.160
TC SFT	North Bay	1999	99.26.1	65	-3.8	0.150
TC SFT	North Bay	1999	99.27.1A	41	-5.5	0.110
TC SFT	North Bay	1999	99.27.1A	41	-5.2	0.120
TC SFT	North Bay	1999	99.27.1A	62	-5.5	0.150
TC SFT	North Bay	1999	99.27.1A	65	-5.5	0.110
TC SFT	North Bay	1999	99.29.3	53		0.35
TC SFT	North Bay	1999	99.29.4	52		0.35
TC SFT	North Bay	1999	99.29.5	52		0.42
TC SFT	Norway	1999	99.61.1	46	-1.1	0.260
TC SFT	Norway	1999	99.61.1	40	-0.6	0.200
TC SFT	Norway	1999	99.61.1	42	-0.4	0.170
TC SFT	Norway	1999	99.61.1	52	-0.5	0.220
TC SFT	Norway	1999	99.61.1	54	-0.2	0.180
TC SFT	Norway	1999	99.61.1	56	-0.2	0.160
TC SFT	Norway	1999	99.61.1	67	-0.4	0.220
TC SFT	Norway	1999	99.61.1	66	-0.3	0.180
TC SFT	Norway	1999	99.61.1	68	-0.2	0.160
TC SFT	North Bay	2000	00.24.3B	67	-7.7	0.060
TC SFT	North Bay	2000	00.24.3B	64	-7.7	0.060
TC SFT	North Bay	2000	00.24.3B	66	-7.7	0.050
TC SFT	North Bay	2000	00.24.3B	65	-7.7	0.070
TC SFT	North Bay	2001	01.23.1	67	-2.1	0.290
TC SFT	North Bay	2001	01.23.1	65	-1.8	0.280
TC SFT	North Bay	2001	01.23.1	66	-1.5	0.260
TC SFT	North Bay	2001	01.23.1	64	-1.2	0.230
TC SFT	North Bay	2001	01.24.3	65	-2.9	0.220
TC SFT	North Bay	2001	01.24.3	65	-2.9	0.210
TC SFT	North Bay	2001	01.24.3	64	-2.9	0.190
TC SFT	North Bay	2001	01.24.3	63	-2.9	0.160

TC SFT	North Bay	2001	01.24.3	66	-2.9	0.170
TC SFT	North Bay	2001	01.24.3	66	-2.9	0.150
TC SFT	North Bay	2001	01.23.1	66		0.210
TC SFT	North Bay	2001	01.23.1	64		0.220
TC SFT	North Bay	2001	01.24.4	64	-2.9	0.150
TC SFT	North Bay	2001	01.24.4	65	-2.9	0.140
TC SFT	North Bay	2001	01.24.4	66	-2.9	0.130
TC SFT	North Bay	2001	01.24.4	64	-2.9	0.140
TC SFT	North Bay	2001	01.24.4	65	-2.9	0.140
TC SFT	North Bay	2001	01.25.1	66	-16	0.150
TC SFT	North Bay	2001	01.25.1	62	-14.5	0.140
TC SFT	North Bay	2001	01.25.1	67	-13	0.130
TC SFT	North Bay	2001	01.25.1	65	-11	0.110
TC SFT	North Bay	2001	01.25.1	65	-9	0.110
TC SFT	North Bay	2001	01.25.1	66	-8.3	0.120
TC SFT	North Bay	2001	01.25.3	66	-8.5	0.070
TC SFT	North Bay	2001	01.25.3	65	-8.5	0.070
TC SFT	North Bay	2001	01.25.3	65	-8.3	0.090
TC SFT	North Bay	2001	01.25.3	66	-8.3	0.090
TC SFT	North Bay	2001	01.25.3	65	-8.3	0.080
TC SFT	North Bay	2001	01.25.3	66	-8.3	0.070
TC SFT	North Bay	2001	01.25.5	67	-4.7	0.030
TC SFT	North Bay	2001	01.25.5	66	-4.7	0.030
TC SFT	North Bay	2001	01.25.5	66	-4.7	0.040
TC SFT	North Bay	2001	01.25.5	65	-4.7	0.030
TC SFT	North Bay	2001	01.25.5	64	-5	0.030
TC SFT	North Bay	2001	01.26.1	64	-6.4	0.180
TC SFT	North Bay	2001	01.26.1	64	-6.4	0.180
TC SFT	North Bay	2001	01.26.1	65	-6.4	0.160
TC SFT	North Bay	2001	01.26.1	65	-6.3	0.150
TC SFT	North Bay	2001	01.26.1	65	-6.2	0.130
TC SFT	North Bay	2001	01.26.4	66	-1.7	0.070
TC SFT	North Bay	2001	01.26.4	64	-1.7	0.060
TC SFT	North Bay	2001	01.26.3	66	-4.1	0.100
TC SFT	North Bay	2001	01.26.3	65	-4.1	0.090
TC SFT	North Bay	2001	01.26.3	65	-4.1	0.100
TC SFT	North Bay	2001	01.26.3	66	-4.1	0.080
TC SFT	North Bay	2001	01.26.3	65	-4.1	0.090
TC SFT	North Bay	2001	01.26.4	65		0.060
TC SFT	North Bay	2001	01.26.4	64		0.050
TC SFT	North Bay	2001	01.27.3A	66	-4	0.060
TC SFT	North Bay	2001	01.27.3A	64	-4	0.060
TC SFT	North Bay	2001	01.27.2	65	-5	0.050
TC SFT	North Bay	2001	01.27.2	64	-5	0.050
TC SFT	North Bay	2001	01.27.2	65	-5	0.030
TC SFT	North Bay	2001	01.27.2	65	-4	0.030
TC SFT	Munich	2001	01.59.1	42	-2.4	0.120
TC SFT	Munich	2001	01.59.1	42	-1.7	0.100

TC SFT	Munich	2001	01.59.1	64	-2.1	0.100
TC SFT	Munich	2001	01.59.1	64	-2.1	0.090
TC SFT	Munich	2001	01.59.1	63	-1.9	0.090
TC SFT	Munich	2001	01.59.1	61	-1.4	0.080
TC SFT	Munich	2001	01.59.1	63	-1.4	0.100
TC SFT	Munich	2001	01.59.1	87	-2.1	0.080
TC SFT	Munich	2001	01.59.6	64		0.130
TC SFT	Munich	2001	01.59.6	65		0.130
TC SFT	Munich	2001	01.59.6	63		0.130
TC SFT	Munich	2001	01.59.6	64		0.130
TC SFT	Munich	2001	01.59.6	63		0.130
TC SFT	Munich	2001	01.59.6	64		0.120
TC SFT	Munich	2001	01.59.6	64		0.130
TC SFT	Munich	2001	01.59.6	62		0.130
TC SFT	Munich	2001	01.59.6	63		0.120
TC SFT	Munich	2001	01.59.6	62		0.120
TC SFT	Munich	2001	01.59.6	61		0.120
TC SFT	Munich	2001	01.59.6	63		0.100
TC SFT	Munich	2001	01.59.6	65		0.100
TC SFT	Munich	2001	01.59.6	66		0.090
TC SFT	Munich	2001	01.59.6	65		0.080
TC SFT	Munich	2001	01.59.6	65		0.080
TC SFT	Munich	2001	01.59.6	65		0.080
TC SFT	Munich	2001	01.60.1	65	-0.2	0.08
TC SFT	Munich	2001	01.60.1	65	-0.2	0.090
TC SFT	Munich	2001	01.60.3	42	-1.5	0.13
TC SFT	Munich	2001	01.60.3	40	-1	0.11
TC SFT	Munich	2001	01.60.3	43	-0.6	0.08
TC SFT	Munich	2001	01.60.3	68	-1.5	0.12
TC SFT	Munich	2001	01.60.3	64	-1	0.11
TC SFT	Munich	2001	01.60.3	62	-0.6	0.08
TC SFT	Munich	2001	01.60.3	87	-1.5	0.12
TC SFT	Munich	2001	01.60.3	92	-1	0.100

Bare Packed Snow

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ
TC SFT	North Bay	1998	98.30.2B	42	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	67	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	68	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	65	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	66	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	41	-3.00	0.210
TC SFT	North Bay	1998	98.30.2B	42	-3.00	0.210
TC SFT	North Bay	1998	98.30.2B	39	-3.00	0.230
TC SFT	North Bay	1998	98.30.2B	86	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	93	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	93	-3.00	0.220
TC SFT	North Bay	1998	98.30.2B	92	-3.00	0.220
TC SFT	North Bay	1998	98.40.2	51	-4.20	0.330
TC SFT	North Bay	1998	98.31.3A	42		0.310
TC SFT	North Bay	1998	98.31.3A	40		0.280
TC SFT	North Bay	1998	98.31.3A	41		0.310
TC SFT	North Bay	1998	98.31.3A	41		0.300
TC SFT	North Bay	1998	98.31.3A	69		0.300
TC SFT	North Bay	1998	98.31.3A	69		0.260
TC SFT	North Bay	1998	98.31.3A	64		0.310
TC SFT	North Bay	1998	98.31.3A	70		0.310
TC SFT	North Bay	1998	98.31.3A	94		0.290
TC SFT	North Bay	1998	98.31.3A	91		0.280
TC SFT	North Bay	1998	98.31.3A	89		0.310
TC SFT	North Bay	1998	98.31.3A	91		0.290
TC SFT	North Bay	1998	98.40.2	48		0.320
TC SFT	North Bay	1998	98.40.2	89		0.340
TC SFT	North Bay	1998	98.40.2	93		0.350
TC SFT	North Bay	1998	98.40.2	102		0.320
TC SFT	North Bay	1998	98.40.2	100		0.330
TC SFT	Norway	1998	98.68.1	48	-6.90	0.250
TC SFT	Norway	1998	98.68.1	69	-6.90	0.250
TC SFT	Norway	1998	98.68.1	85	-6.90	0.250
TC SFT	Norway	1998	98.69.2	47	-12.40	0.270
TC SFT	Norway	1998	98.69.2	69	-12.20	0.250
TC SFT	Norway	1998	98.69.2	91	-12.00	0.270
TC SFT	Norway	1998	98.69.3	41	-9.30	0.240
TC SFT	Norway	1998	98.69.3	66	-9.00	0.220
TC SFT	Norway	1998	98.69.3	77	-8.90	0.210
TC SFT	Norway	1998	98.70.2B	49		0.220
TC SFT	Norway	1998	98.69.5	43	-7.70	0.200
TC SFT	Norway	1998	98.69.5	65	-7.70	0.190
TC SFT	Norway	1998	98.69.5	87	-7.70	0.170
TC SFT	Norway	1998	98.70.2A	40	-7.80	0.250

TC SFT	Norway	1998	98.70.2A	65	-7.30	0.260
TC SFT	Norway	1998	98.70.2A	90	-7.00	0.220
TC SFT	Norway	1998	98.70.2B	68	-6.90	0.230
TC SFT	Norway	1998	98.70.2B	85	-6.70	0.200
TC SFT	Norway	1998	98.70.2C	46	-6.70	0.220
TC SFT	Norway	1998	98.70.2C	67	-6.50	0.210
TC SFT	Norway	1998	98.70.2C	86	-6.50	0.180
TC SFT	Norway	1998	98.72.2A.1	47	-4.90	0.220
TC SFT	Norway	1998	98.72.2A.1	66	-4.80	0.250
TC SFT	Norway	1998	98.72.2A.1	83	-4.80	0.220
TC SFT	North Bay	1999	99.22.1	40		0.210
TC SFT	North Bay	1999	99.22.1	41		0.250
TC SFT	North Bay	1999	99.22.1	41		0.160
TC SFT	North Bay	1999	99.22.1	41		0.150
TC SFT	North Bay	1999	99.22.1	50		0.240
TC SFT	North Bay	1999	99.22.1	51		0.240
TC SFT	North Bay	1999	99.22.1	50		0.180
TC SFT	North Bay	1999	99.22.1	53		0.210
TC SFT	North Bay	1999	99.22.1	65		0.230
TC SFT	North Bay	1999	99.22.1	66		0.230
TC SFT	North Bay	1999	99.22.1	65		0.210
TC SFT	North Bay	1999	99.22.1	66		0.190
TC SFT	Sawyer Field	1999	99.34.1	40		0.270
TC SFT	Sawyer Field	1999	99.34.1	67		0.280
TC SFT	Sawyer Field	1999	99.34.1	64		0.270
TC SFT	Sawyer Field	1999	99.34.1	91		0.280
TC SFT	Sawyer Field	1999	99.34.1	90		0.270
TC SFT	Sawyer Field	1999	99.32.2A	50		0.160
TC SFT	Sawyer Field	1999	99.34.1	39		0.270
TC SFT	Sawyer Field	1999	99.35.1	40	-9.00	0.170
TC SFT	Sawyer Field	1999	99.35.1	39	-9.00	0.190
TC SFT	Sawyer Field	1999	99.35.1	41	-9.00	0.160
TC SFT	Sawyer Field	1999	99.35.1	39	-9.00	0.190
TC SFT	Sawyer Field	1999	99.35.1	52	-8.50	0.200
TC SFT	Sawyer Field	1999	99.35.1	51	-8.50	0.210
TC SFT	Sawyer Field	1999	99.35.1	53	-9.00	0.200
TC SFT	Sawyer Field	1999	99.35.1	52	-9.00	0.210
TC SFT	Sawyer Field	1999	99.35.1	64	-8.50	0.200
TC SFT	Sawyer Field	1999	99.35.1	64	-9.00	0.190
TC SFT	Sawyer Field	1999	99.35.1	65	-9.00	0.160
TC SFT	Sawyer Field	1999	99.35.1	65	-9.00	0.200
TC SFT	Sawyer Field	1999	99.35.2	52	-8.50	0.180
TC SFT	Sawyer Field	1999	99.35.2	41	-8.50	0.200
TC SFT	Sawyer Field	1999	99.35.2	41	-8.50	0.190
TC SFT	Sawyer Field	1999	99.35.2	39	-8.90	0.180
TC SFT	Sawyer Field	1999	99.35.2	41	-8.90	0.180
TC SFT	Sawyer Field	1999	99.35.2	51	-8.40	0.210
TC SFT	Sawyer Field	1999	99.35.2	51	-8.40	0.190

TC SFT	Sawyer Field	1999	99.35.2	51	-8.90	0.180
TC SFT	Sawyer Field	1999	99.35.2	65	-7.90	0.200
TC SFT	Sawyer Field	1999	99.35.2	64	-8.00	0.230
TC SFT	Sawyer Field	1999	99.35.2	65	-8.20	0.190
TC SFT	Sawyer Field	1999	99.35.2	64	-8.30	0.210
TC SFT	Sawyer Field	1999	99.36.1A	40		0.190
TC SFT	Sawyer Field	1999	99.36.1A	52		0.180
TC SFT	Sawyer Field	1999	99.35.4	50	-11.00	0.140
TC SFT	Sawyer Field	1999	99.35.5	50		0.160
TC SFT	Sawyer Field	1999	99.36.1A	65	-6.00	0.180
TC SFT	Sawyer Field	1999	99.37.3	50		0.120
TC SFT	Sawyer Field	1999	99.37.4	50		0.170
TC SFT	Sawyer Field	1999	99.38.1	50		0.210
TC SFT	Sawyer Field	1999	99.38.2	40		0.180
TC SFT	Sawyer Field	1999	99.38.2	50		0.190
TC SFT	Sawyer Field	1999	99.38.2	65		0.190
TC SFT	Norway	1999	99.61.2	46	-1.90	0.240
TC SFT	Norway	1999	99.61.2	50	-1.00	0.260
TC SFT	Norway	1999	99.61.2	46	-1.00	0.240
TC SFT	Norway	1999	99.61.2	46	-1.00	0.220
TC SFT	Norway	1999	99.61.2	64	-1.90	0.220
TC SFT	Norway	1999	99.61.2	74	-1.00	0.230
TC SFT	Norway	1999	99.61.2	67	-1.00	0.210
TC SFT	Norway	1999	99.61.2	67	-1.00	0.230
TC SFT	Norway	1999	99.61.2	75	-1.90	0.230
TC SFT	Norway	1999	99.61.2	84	-1.00	0.230
TC SFT	Norway	1999	99.61.2	87	-1.00	0.210
TC SFT	Norway	1999	99.61.2	82	-1.00	0.240
TC SFT	North Bay	2001	01.25.2	64	-12.20	0.200
TC SFT	North Bay	2001	01.25.2	64	-12.20	0.230
TC SFT	North Bay	2001	01.25.2	66	-12.20	0.210
TC SFT	North Bay	2001	01.25.2	64	-12.20	0.210
TC SFT	North Bay	2001	01.25.2	67	-12.20	0.240
TC SFT	North Bay	2001	01.25.2	64	-12.20	0.230
TC SFT	North Bay	2001	01.25.4	65	-10.90	0.200
TC SFT	North Bay	2001	01.25.4	65	-10.90	0.210
TC SFT	North Bay	2001	01.25.4	64	-10.90	0.210
TC SFT	North Bay	2001	01.25.4	65	-10.90	0.210
TC SFT	North Bay	2001	01.25.4	63	-10.90	0.210
TC SFT	North Bay	2001	01.25.4	66	-10.90	0.210
TC SFT	North Bay	2001	01.26.2	64	-7.60	0.260
TC SFT	North Bay	2001	01.26.2	66	-7.60	0.250
TC SFT	North Bay	2001	01.26.2	65	-7.60	0.260
TC SFT	North Bay	2001	01.26.2	64	-7.60	0.240
TC SFT	North Bay	2001	01.26.2	65	-7.60	0.250
TC SFT	North Bay	2001	01.26.5	65	-3.90	0.250
TC SFT	North Bay	2001	01.26.5	66	-3.90	0.220
TC SFT	North Bay	2001	01.26.5	65	-3.90	0.250

TC SFT	North Bay	2001	01.26.5	66	-3.90	0.240
TC SFT	North Bay	2001	01.27.1	67	-9.50	0.200
TC SFT	North Bay	2001	01.27.1	64	-10.00	0.230
TC SFT	North Bay	2001	01.27.1	65	-9.70	0.180
TC SFT	North Bay	2001	01.27.1	66	-9.90	0.200
TC SFT	North Bay	2001	01.27.4	65	-7.80	0.230
TC SFT	North Bay	2001	01.27.4	65	-7.80	0.280
TC SFT	North Bay	2001	01.27.3B	66	-7.80	0.210
TC SFT	North Bay	2001	01.27.3B	66	-7.80	0.280
TC SFT	North Bay	2001	01.27.5	64	-8.80	0.270
TC SFT	North Bay	2001	01.27.5	65	-8.80	0.270

Loose Snow on Pavement <= 3 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	Depth
				(km/h)	(°C)		(mm)
TC SFT	Norway	1999	99.62.4	46	-2.3	0.130	1.5
TC SFT	Norway	1999	99.62.4	43	-2.1	0.110	1.5
TC SFT	Norway	1999	99.62.4	45	-1.9	0.100	1.5
TC SFT	Norway	1999	99.62.4	43	-1.7	0.100	1.5
TC SFT	Norway	1999	99.62.4	65	-2.3	0.120	1.5
TC SFT	Norway	1999	99.62.4	64	-2.1	0.100	1.5
TC SFT	Norway	1999	99.62.4	62	-1.9	0.120	1.5
TC SFT	Norway	1999	99.62.4	77	-2.3	0.100	1.5
TC SFT	Norway	1999	99.62.4	72	-2.1	0.120	1.5

Loose Snow on Pavement Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ	Depth
TC SFT	Norway	1999	99.62.2A	45	-3.8	0.170	10
TC SFT	Norway	1999	99.62.2A	68	-3.8	0.160	10
TC SFT	Norway	1999	99.62.2A	79	-3.8	0.160	10
TC SFT	Norway	1999	99.62.3	44	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	46	-3.0	0.150	25
TC SFT	Norway	1999	99.62.3	44	-3.0	0.150	25
TC SFT	Norway	1999	99.62.3	45	-3.0	0.120	25
TC SFT	Norway	1999	99.62.3	61	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	69	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	65	-3.0	0.150	25
TC SFT	Norway	1999	99.62.3	64	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	80	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	82	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	83	-3.0	0.140	25
TC SFT	Norway	1999	99.62.3	75	-3.0	0.140	25
TC SFT	North Bay	2000	00.23.4	66		0.180	15
TC SFT	North Bay	2000	00.23.4	67		0.190	15
TC SFT	North Bay	2000	00.23.4	68		0.180	15
TC SFT	North Bay	2001	01.33.1	66	-4.0	0.140	20
TC SFT	North Bay	2001	01.33.1	64	-4.0	0.130	20
TC SFT	North Bay	2001	01.33.1	65	-4.0	0.120	20
TC SFT	Munich	2001	01.61.2	65	-1.5	0.280	24
TC SFT	Munich	2001	01.61.2	64	-1.5	0.300	24
TC SFT	Munich	2001	01.61.2	67	-1.5	0.280	24
TC SFT	Munich	2001	01.61.2	64	-1.5	0.280	24
TC SFT	Munich	2001	01.61.2	66	-1.5	0.300	24
TC SFT	Munich	2001	01.61.2	66	-1.5	0.330	24
TC SFT	Munich	2001	01.61.2	66	-1.5	0.330	24
TC SFT	Munich	2001	01.61.2	65	-1.5	0.330	24
TC SFT	Munich	2001	01.61.2	66	-1.5	0.300	24
TC SFT	Munich	2001	01.61.2	65	-1.5	0.390	24
TC SFT	Munich	2001	01.61.2	66	-1.5	0.440	24
TC SFT	Munich	2001	01.61.3	69	0.0	0.280	8
TC SFT	Munich	2001	01.61.3	66	0.0	0.150	8
TC SFT	Munich	2001	01.61.3	64	0.0	0.160	8
TC SFT	Munich	2001	01.61.3	65	0.0	0.300	8

Loose Snow on Ice <= 3 mm

Device	Site	Year	Test no.	Speed (km/h)	Temp. (°C)	Avg. μ	Depth (mm)
TC SFT	North Bay	2000	00.23.2	68	-14.5	0.170	0.1
TC SFT	North Bay	2000	00.23.2	68	-14.5	0.160	0.1
TC SFT	North Bay	2000	00.23.2	67	-14.5	0.150	0.1

Loose Snow on Ice Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ	Depth
				(km/h)	(°C)		(mm)
TC SFT	North Bay	1999	99.19.2	40	-1.0	0.160	5
TC SFT	North Bay	1999	99.19.2	40	-1.0	0.150	5
TC SFT	North Bay	1999	99.19.2	41	-1.0	0.150	5
TC SFT	North Bay	1999	99.19.2	40	-1.0	0.120	5
TC SFT	North Bay	1999	99.19.2	52	-1.0	0.160	5
TC SFT	North Bay	1999	99.19.2	51	-1.0	0.170	5
TC SFT	North Bay	1999	99.19.2	50	-1.0	0.120	5
TC SFT	North Bay	1999	99.19.2	50	-1.0	0.110	5
TC SFT	North Bay	1999	99.19.2	69	-1.0	0.180	5
TC SFT	North Bay	1999	99.19.2	66	-1.0	0.180	5
TC SFT	North Bay	1999	99.19.2	64	-1.0	0.140	5
TC SFT	North Bay	1999	99.19.2	65	-1.0	0.140	5
TC SFT	North Bay	1999	99.20.1B	41	-4.5	0.120	5
TC SFT	North Bay	1999	99.20.1B	41	-4.5	0.120	5
TC SFT	North Bay	1999	99.20.1B	41	-4.5	0.090	5
TC SFT	North Bay	1999	99.20.1B	40	-4.5	0.080	5
TC SFT	North Bay	1999	99.20.1B	51	-4.5	0.130	5
TC SFT	North Bay	1999	99.20.1B	51	-4.5	0.140	5
TC SFT	North Bay	1999	99.20.1B	51	-4.5	0.070	5
TC SFT	North Bay	1999	99.20.1B	50	-4.5	0.090	5
TC SFT	North Bay	1999	99.20.1B	66	-4.5	0.150	5
TC SFT	North Bay	1999	99.20.1B	64	-4.5	0.140	5
TC SFT	North Bay	1999	99.20.1B	64	-4.5	0.080	5
TC SFT	North Bay	1999	99.20.1B	64	-4.5	0.080	5
TC SFT	North Bay	1999	99.20.1B	81	-4.5	0.100	5
TC SFT	North Bay	1999	99.20.1B	80	-4.5	0.080	5
TC SFT	North Bay	2000	00.19.3	30	-9.6	0.160	6
TC SFT	North Bay	2000	00.19.3	30	-9.6	0.150	6
TC SFT	North Bay	2000	00.19.3	45	-9.6	0.150	6
TC SFT	North Bay	2000	00.19.3	45	-9.6	0.150	6
TC SFT	North Bay	2000	00.19.3	65	-9.6	0.150	6
TC SFT	North Bay	2000	00.19.3	65	-9.6	0.160	6
TC SFT	North Bay	2001	01.22.1	64	-6.5	0.230	5
TC SFT	North Bay	2001	01.22.1	66	-6.5	0.290	5
TC SFT	North Bay	2001	01.22.1	71	-6.5	0.370	5
TC SFT	North Bay	2001	01.24.1	62	-1.7	0.130	17
TC SFT	North Bay	2001	01.24.1	64	-1.7	0.160	17
TC SFT	North Bay	2001	01.24.1	66	-1.7	0.150	17

Loose Snow on Packed Snow Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	Depth
				(km/h)	(°C)		(mm)
TC SFT	North Bay	1998	98.37.3	41	-5.1	0.230	8
TC SFT	North Bay	1998	98.37.3	71	-5.1	0.230	8
TC SFT	North Bay	1998	98.37.3	67	-5.1	0.230	8
TC SFT	North Bay	1998	98.37.3	77	-5.1	0.250	8
TC SFT	North Bay	1998	98.37.3	85	-5.1	0.260	8
TC SFT	North Bay	2001	01.32.1	65	-10.5	0.250	5
TC SFT	North Bay	2001	01.32.1	64	-10.5	0.250	5
TC SFT	North Bay	2001	01.32.1	65	-10.5	0.260	5
TC SFT	North Bay	2001	01.32.1	64	-10.5	0.250	5
TC SFT	North Bay	2001	01.32.1	65	-10.5	0.250	5

APPENDIX A.3

IRV DATA

Bare Ice

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	North Bay	2000	00.18.12	65		0.230	0.140
IRV	North Bay	2000	00.18.12	65		0.250	0.170
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.230	0.160
IRV	North Bay	2000	00.18.12	66		0.210	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.13	67		0.230	0.170
IRV	North Bay	2000	00.18.13	67		0.210	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.160
IRV	North Bay	2000	00.18.13	67		0.220	0.140
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.22	38	-21.4	0.240	0.160
IRV	North Bay	2000	00.18.22	64	-21.4	0.240	0.160
IRV	North Bay	2000	00.18.22	85	-21.4	0.200	0.130
IRV	North Bay	2000	00.18.23	42		0.210	0.130
IRV	North Bay	2000	00.18.23	67		0.210	0.120
IRV	North Bay	2000	00.18.23	86		0.210	0.120
IRV	North Bay	2000	00.18.32	68		0.140	0.080
IRV	North Bay	2000	00.18.32	65		0.160	0.080
IRV	North Bay	2000	00.18.32	65		0.160	0.080
IRV	North Bay	2000	00.18.33	67		0.220	0.140
IRV	North Bay	2000	00.18.33	67		0.210	0.130
IRV	North Bay	2000	00.18.33	67		0.210	0.120
IRV	North Bay	2000	00.20.3	64		0.250	0.160
IRV	North Bay	2000	00.20.3	65		0.270	0.180
IRV	North Bay	2000	00.20.3	65		0.230	0.160
IRV	North Bay	2000	00.20.3	65		0.230	0.160
IRV	North Bay	2000	00.20.3	63		0.230	0.160
IRV	North Bay	2000	00.20.3	65		0.240	0.160
IRV	North Bay	2000	00.20.3	63		0.240	0.160
IRV	North Bay	2000	00.20.3	63		0.260	0.180
IRV	North Bay	2000	00.21.2	68		0.220	0.150
IRV	North Bay	2000	00.21.2	68		0.200	0.140
IRV	North Bay	2000	00.21.2	68		0.210	0.150
IRV	North Bay	2000	00.21.2	68		0.210	0.140
IRV	North Bay	2000	00.21.2	68		0.200	0.140
IRV	North Bay	2000	00.21.2	68		0.190	0.130
IRV	North Bay	2000	00.21.2	68		0.190	0.130
IRV	North Bay	2000	00.21.5	67		0.160	0.080
IRV	North Bay	2000	00.21.5	68		0.160	0.090
IRV	North Bay	2000	00.21.5	67		0.160	0.090

IRV	North Bay	2000	00.21.5	67		0.160	0.090
IRV	North Bay	2000	00.21.5	68		0.180	0.110
IRV	North Bay	2000	00.21.5	67		0.180	0.110
IRV	North Bay	2000	00.21.5	67		0.160	0.090
IRV	North Bay	2000	00.23.1	67	-14	0.250	0.130
IRV	North Bay	2000	00.23.1	67	-14	0.250	0.140
IRV	North Bay	2000	00.24.3B	68	-8.8	0.150	0.100
IRV	North Bay	2000	00.24.3B	68	-8.8	0.150	0.100
IRV	North Bay	2000	00.24.3B	68	-8.8	0.150	0.100
IRV	North Bay	2000	00.24.3B	67	-9	0.140	0.090
IRV	North Bay	2000	00.25.2B	66		0.160	0.090
IRV	North Bay	2000	00.25.2B	66		0.160	0.090
IRV	North Bay	2000	00.25.2B	66		0.170	0.090
IRV	North Bay	2000	00.25.31B	61	-24.3	0.240	0.130
IRV	North Bay	2000	00.25.31B	68	-24.3	0.260	0.170
IRV	North Bay	2000	00.25.31B	68	-24.3	0.260	0.150
IRV	North Bay	2000	00.25.31B	68	-24.4	0.270	0.150
IRV	North Bay	2000	00.25.3B	66		0.160	0.090
IRV	North Bay	2000	00.25.3B	66		0.160	0.080
IRV	North Bay	2000	00.25.3B	66		0.150	0.080
IRV	North Bay	2000	00.25.4B	66		0.150	0.080
IRV	North Bay	2000	00.25.4B	66		0.160	0.050
IRV	North Bay	2000	00.25.4B	66		0.150	0.080
IRV	North Bay	2000	00.25.5B	66		0.150	0.080
IRV	North Bay	2000	00.25.5B	66		0.150	0.090
IRV	North Bay	2000	00.25.5B	66		0.160	0.070
IRV	North Bay	2000	00.25.6B	66		0.140	0.060
IRV	North Bay	2000	00.25.6B	66		0.150	0.060
IRV	North Bay	2000	00.25.6B	66		0.140	0.060
IRV	North Bay	2000	00.25.7B	66		0.140	0.060
IRV	North Bay	2000	00.25.7B	66		0.140	0.080
IRV	North Bay	2000	00.27.11B	67		0.220	0.110
IRV	North Bay	2000	00.27.11B	67		0.210	0.110
IRV	North Bay	2000	00.27.11B	67		0.220	0.130
IRV	North Bay	2000	00.27.51B	66	-18	0.190	0.100
IRV	North Bay	2000	00.27.51B	66	-18	0.200	0.120
IRV	North Bay	2000	00.27.51B	66	-18	0.200	0.080
IRV	North Bay	2001	01.23.1	65	-3.2		0.280
IRV	North Bay	2001	01.23.1	65	-3.2		0.270
IRV	North Bay	2001	01.23.1	66	-3.2		0.260
IRV	North Bay	2001	01.23.1	66	-1.9	0.300	0.230
IRV	North Bay	2001	01.23.1	65	-1.9	0.280	0.210
IRV	North Bay	2001	01.23.1	66	-1.9	0.260	0.190
IRV	North Bay	2001	01.24.3	65	-5	0.210	0.120
IRV	North Bay	2001	01.24.3	66		0.200	0.100
IRV	North Bay	2001	01.24.3	66		0.190	0.080
IRV	North Bay	2001	01.24.4	65	-5	0.180	0.080
IRV	North Bay	2001	01.24.4	66		0.200	0.100

IRV	North Bay	2001	01.24.4	66		0.180	0.090
IRV	North Bay	2001	01.24.4	66		0.180	0.090
IRV	North Bay	2001	01.24.4	66		0.190	0.090
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.26.1	67	-6.3	0.180	0.110
IRV	North Bay	2001	01.26.1	66	-5.5	0.170	0.110
IRV	North Bay	2001	01.26.1	66	-5.5	0.210	0.150
IRV	North Bay	2001	01.26.1	66	-5.4	0.160	0.100
IRV	North Bay	2001	01.26.1	66		0.220	0.160
IRV	North Bay	2001	01.26.3	65	-3.5	0.160	0.080
IRV	North Bay	2001	01.26.3	66		0.150	0.080
IRV	North Bay	2001	01.26.3	66		0.150	0.080
IRV	North Bay	2001	01.26.3	66		0.140	0.070
IRV	North Bay	2001	01.26.3	67		0.140	0.080
IRV	North Bay	2001	01.27.2	65	-12.2	0.130	0.050
IRV	North Bay	2001	01.27.2	65	-12.2	0.110	0.040
IRV	North Bay	2001	01.27.2	65	-12.2	0.100	0.030
IRV	North Bay	2001	01.29.3	68	-3.3	0.150	0.080
IRV	North Bay	2001	01.29.3	67		0.150	0.080
IRV	North Bay	2001	01.29.3	68		0.140	0.070
IRV	North Bay	2001	01.81.1	70	-1	0.160	0.120
IRV	North Bay	2001	01.81.1	65	2.7	0.150	0.110
IRV	North Bay	2001	01.81.1	64		0.130	0.090
IRV	North Bay	2001	01.81.1	62		0.150	0.100
IRV	North Bay	2001	01.81.1	56		0.150	0.110
IRV	North Bay	2001	01.81.1	63		0.150	0.110
IRV	North Bay	2002	02.35.1	65	-17.1	0.110	0.080
IRV	North Bay	2002	02.35.1	65	-13.8	0.100	0.070
IRV	North Bay	2002	02.35.1	65	-14	0.100	0.070
IRV	North Bay	2002	02.35.1	65		0.100	0.070
IRV	North Bay	2002	02.35.1	65		0.100	0.070
IRV	North Bay	2002	02.35.3	64	-15.5	0.130	0.100
IRV	North Bay	2002	02.35.3	64	-15.6	0.110	0.080
IRV	North Bay	2002	02.35.3	64		0.090	0.060
IRV	North Bay	2002	02.35.3	64		0.090	0.050
IRV	North Bay	2002	02.35.3	64		0.080	0.050
IRV	North Bay	2002	02.35.3	64		0.080	0.050
IRV	North Bay	2002	02.35.3	64		0.090	0.060
IRV	North Bay	2002	02.35.5	64	-15.6	0.090	0.060
IRV	North Bay	2002	02.35.5	63	-15.5	0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.050
IRV	North Bay	2002	02.35.5	63		0.080	0.050
IRV	North Bay	2002	02.35.5	63		0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.040
IRV	North Bay	2002	02.38.3	64	2.6	0.210	0.180

IRV	North Bay	2002	02.38.3	64	2.6	0.190	0.170
IRV	North Bay	2002	02.38.3	64		0.190	0.170
IRV	North Bay	2002	02.38.3	65		0.190	0.170
IRV	North Bay	2002	02.38.3	64		0.190	0.170
IRV	North Bay	2002	02.39.1	64	-13.5	0.300	0.270
IRV	North Bay	2002	02.39.1	64	-12.8	0.290	0.280
IRV	North Bay	2002	02.39.1	65		0.300	0.290
IRV	North Bay	2002	02.39.1	65		0.290	0.270
IRV	North Bay	2002	02.39.1	65		0.280	0.270
IRV	North Bay	2003	03.27.1	65	-26.2	0.210	0.200
IRV	North Bay	2003	03.27.1	65	-23.1	0.200	0.190
IRV	North Bay	2003	03.27.1	65		0.190	0.170
IRV	North Bay	2003	03.27.1	65		0.180	0.160
IRV	North Bay	2003	03.27.1	65		0.160	0.150
IRV	North Bay	2003	03.27.1	65		0.160	0.140
IRV	North Bay	2003	03.28.2	64	-14.6	0.140	0.120
IRV	North Bay	2003	03.28.2	64		0.140	0.120
IRV	North Bay	2003	03.28.2	64	-12.6	0.130	0.120
IRV	North Bay	2003	03.28.2	65		0.130	0.120
IRV	North Bay	2003	03.28.2	64		0.130	0.120
IRV	North Bay	2003	03.29.1	64	-17.6	0.140	0.130
IRV	North Bay	2003	03.29.1	64		0.120	0.110
IRV	North Bay	2003	03.29.1	64	-17.5	0.110	0.100
IRV	North Bay	2003	03.29.1	64		0.110	0.100
IRV	North Bay	2003	03.29.1	64		0.110	0.090
IRV	North Bay	2003	03.30.4	65		0.110	0.100
IRV	North Bay	2003	03.30.4	65		0.100	0.090
IRV	North Bay	2003	03.30.4	65		0.090	0.080
IRV	North Bay	2003	03.30.4	64		0.110	0.090
IRV	New Chitose	2003	03.42.1	66	-5	0.120	0.100
IRV	New Chitose	2003	03.42.1	66	-5.1	0.130	0.120
IRV	New Chitose	2003	03.42.1	67		0.150	0.140
IRV	New Chitose	2003	03.42.1	67		0.150	0.140
IRV	New Chitose	2003	03.42.1	66		0.200	0.190
IRV	New Chitose	2003	03.43.1	64	-4.1	0.160	0.150
IRV	New Chitose	2003	03.43.1	65	-4	0.180	0.170
IRV	New Chitose	2003	03.43.1	66		0.170	0.160
IRV	New Chitose	2003	03.43.1	66		0.180	0.180
IRV	New Chitose	2003	03.43.1	66		0.180	0.180
IRV	New Chitose	2003	03.43.3A	66	-5.3	0.140	0.130

Bare Packed Snow

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(^{o}C)	IRV-Force	IRV-Torque
IRV	North Bay	2000	00.26.11	67	-20.4	0.270	0.170
IRV	North Bay	2000	00.26.11	67	-20.4	0.280	0.200
IRV	North Bay	2000	00.26.11	67	-20.4	0.280	0.210
IRV	North Bay	2000	00.26.11	67	-20.4	0.270	0.200
IRV	North Bay	2000	00.26.11	66	-20.4	0.270	0.180
IRV	North Bay	2000	00.26.51	65	-16.5	0.230	0.140
IRV	North Bay	2000	00.26.51	65	-16.5	0.240	0.160
IRV	North Bay	2000	00.26.51	65	-16.5	0.230	0.160
IRV	North Bay	2000	00.26.52	65		0.240	0.150
IRV	North Bay	2000	00.26.52	65		0.240	0.160
IRV	North Bay	2000	00.26.52	65		0.240	0.150
IRV	North Bay	2000	00.26.53	65		0.230	0.140
IRV	North Bay	2000	00.26.53	65		0.240	0.160
IRV	North Bay	2000	00.26.53	65		0.240	0.160
IRV	North Bay	2000	00.26.54	65		0.240	0.150
IRV	North Bay	2000	00.26.54	65		0.240	0.170
IRV	North Bay	2000	00.26.54	65		0.260	0.170
IRV	North Bay	2000	00.27.12	67		0.250	0.140
IRV	North Bay	2000	00.27.12	67		0.250	0.160
IRV	North Bay	2000	00.27.12	67		0.250	0.160
IRV	North Bay	2000	00.27.52	66	-17.0	0.250	0.160
IRV	North Bay	2000	00.27.52	67	-17.0	0.240	0.160
IRV	North Bay	2000	00.27.52	66	-17.0	0.240	0.150
IRV	North Bay	2000	00.26.21	41		0.260	0.200
IRV	North Bay	2000	00.26.21	67		0.250	0.180
IRV	North Bay	2000	00.26.21	88		0.250	0.170
IRV	North Bay	2000	00.26.31	68		0.240	0.160
IRV	North Bay	2001	01.26.2	65	-6.4	0.320	0.250
IRV	North Bay	2001	01.26.2	66	-6.4	0.310	0.250
IRV	North Bay	2001	01.26.2	66	-6.4	0.300	0.240
IRV	North Bay	2001	01.26.2	66	-6.4	0.300	0.250
IRV	North Bay	2001	01.26.2	65	-6.4	0.300	0.240
IRV	North Bay	2001	01.27.1	68	-12.2	0.290	0.200
IRV	North Bay	2001	01.27.1	67	-12.2	0.300	0.230
IRV	North Bay	2001	01.27.1	67	-12.5	0.190	0.120
IRV	North Bay	2002	02.35.2	65	-13.8	0.260	0.220
IRV	North Bay	2002	02.35.2	65	-14.0	0.230	0.190
IRV	North Bay	2002	02.35.2	65	-14.0	0.220	0.180
IRV	North Bay	2002	02.35.2	65	-14.0	0.230	0.190
IRV	North Bay	2002	02.35.2	65	-14.0	0.220	0.180
IRV	North Bay	2002	02.35.4	64	-14.0	0.240	0.200
IRV	North Bay	2002	02.35.4	64	-15.6	0.230	0.190
IRV	North Bay	2002	02.35.4	64	-15.0	0.240	0.200
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.190

IRV	North Bay	2002	02.35.4	64	-15.0	0.220	0.190
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.200
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.190
IRV	North Bay	2002	02.35.6	64	-15.6	0.260	0.220
IRV	North Bay	2002	02.35.6	64	-15.5	0.260	0.210
IRV	North Bay	2002	02.35.6	64	-15.5	0.240	0.200
IRV	North Bay	2002	02.35.6	65	-15.5	0.250	0.200
IRV	North Bay	2002	02.35.6	65	-15.5	0.250	0.200
IRV	North Bay	2002	02.35.6	64	-15.5	0.270	0.230
IRV	North Bay	2002	02.35.6	64	-15.5	0.240	0.190
IRV	North Bay	2002	02.36.7	63	-6.3	0.230	0.180
IRV	North Bay	2002	02.36.7	63	-6.4	0.210	0.160
IRV	North Bay	2002	02.36.7	63	-6.4	0.230	0.180
IRV	North Bay	2002	02.36.7	63	-6.4	0.210	0.150
IRV	North Bay	2002	02.36.7	64	-6.4	0.210	0.150
IRV	North Bay	2002	02.36.7	64	-6.4	0.200	0.140
IRV	North Bay	2002	02.36.7	64	-6.4	0.240	0.190
IRV	North Bay	2002	02.37.2	67	-0.3	0.220	0.170
IRV	North Bay	2002	02.37.2	67	-3.0	0.210	0.160
IRV	North Bay	2002	02.37.2	67	-3.0	0.230	0.180
IRV	North Bay	2002	02.37.2	65	-3.0	0.260	0.220
IRV	North Bay	2002	02.37.2	65	-3.0	0.240	0.200
IRV	North Bay	2002	02.37.2	65	-3.0	0.230	0.180
IRV	North Bay	2002	02.38.1	65	-1.3	0.210	0.180
IRV	North Bay	2002	02.38.1	66	-1.3	0.210	0.160
IRV	North Bay	2002	02.38.1	66	-1.3	0.200	0.160
IRV	North Bay	2002	02.38.1	66	-1.3	0.220	0.180
IRV	North Bay	2002	02.38.1	65	-1.3	0.200	0.170
IRV	North Bay	2002	02.38.1	65	-1.3	0.190	0.150
IRV	North Bay	2002	02.38.2	65	-1.3	0.230	0.190
IRV	North Bay	2002	02.38.2	66	-1.8	0.220	0.180
IRV	North Bay	2002	02.38.2	66	-1.8	0.210	0.180
IRV	North Bay	2002	02.38.2	64	-1.8	0.220	0.180
IRV	North Bay	2002	02.38.2	64	-1.8	0.220	0.190
IRV	North Bay	2002	02.38.2	65	-1.8	0.210	0.180
IRV	North Bay	2002	02.38.4	64	2.6	0.320	0.280
IRV	North Bay	2002	02.38.4	63	2.6	0.320	0.280
IRV	North Bay	2002	02.38.4	64	2.6	0.310	0.270
IRV	North Bay	2002	02.38.4	64	2.6	0.300	0.260
IRV	North Bay	2002	02.38.4	64	2.6	0.300	0.260
IRV	North Bay	2002	02.39.3	65	-12.8	0.210	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.200	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.190	0.160
IRV	North Bay	2002	02.39.3	65	-12.8	0.200	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.190	0.160
IRV	North Bay	2002	02.39.3	64	-12.8	0.210	0.190
IRV	North Bay	2002	02.39.4	65	-12.8	0.280	0.250
IRV	North Bay	2002	02.39.4	64	-12.8	0.260	0.230

IRV	North Bay	2002	02.39.4	65	-12.8	0.270	0.240
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.200
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.190
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.200
IRV	North Bay	2003	03.28.1	65	-12.6	0.240	0.210
IRV	North Bay	2003	03.28.1	65	-12.6	0.260	0.240
IRV	North Bay	2003	03.28.1	65	-11.8	0.250	0.230
IRV	North Bay	2003	03.28.1	65	-11.8	0.260	0.240
IRV	North Bay	2003	03.28.1	65	-11.8	0.260	0.240
IRV	North Bay	2003	03.29.2	64	-17.3	0.250	0.230
IRV	North Bay	2003	03.29.2	64	-16.5	0.250	0.240
IRV	North Bay	2003	03.29.2	64	-16.5	0.250	0.240
IRV	North Bay	2003	03.29.2	64	-16.5	0.270	0.250
IRV	North Bay	2003	03.29.2	64	-16.5	0.260	0.250
IRV	North Bay	2003	03.29.6	65	-14.7	0.250	0.230
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	New Chitose	2003	03.42.2	67		0.280	0.270
IRV	New Chitose	2003	03.42.2	65		0.300	0.290
IRV	New Chitose	2003	03.42.2	66		0.300	0.290
IRV	New Chitose	2003	03.42.2	67		0.310	0.300
IRV	New Chitose	2003	03.42.2	65		0.320	0.300
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.260
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.260
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.270
IRV	New Chitose	2003	03.43.2	66	-9.4	0.270	0.270
IRV	New Chitose	2003	03.43.2	66	-9.4	0.300	0.290
IRV	New Chitose	2003	03.44.1	64	-1.6	0.260	0.240
IRV	New Chitose	2003	03.44.1	64	-2.3	0.280	0.250
IRV	New Chitose	2003	03.44.1	64	-2.3	0.250	0.230
IRV	New Chitose	2003	03.44.1	64	-2.3	0.270	0.250
IRV	New Chitose	2003	03.44.1	64	-2.3	0.280	0.260

Sanded Ice

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	New Chitose	2003	03.43.3B	66	-1.6	0.390	0.370
IRV	New Chitose	2003	03.43.3B	66		0.370	0.350
IRV	New Chitose	2003	03.43.3B	66		0.390	0.380
IRV	New Chitose	2003	03.43.3B	66			0.400
IRV	New Chitose	2003	03.43.3B	66		0.400	0.390

Sanded Packed Snow

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	North Bay	2001	01.32.5	67	-6.8	0.350	0.280
IRV	North Bay	2001	01.32.5	68	-6.8	0.360	0.280
IRV	North Bay	2001	01.32.5	68		0.350	0.280

Loose Snow on Pavement <= 3 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2001	01.31.2	67	-6.1	0.190	0.110	3
IRV	North Bay	2002	01.31.3	67		0.220	0.120	3
IRV	North Bay	2003	01.31.4	68		0.210	0.110	3

Loose Snow on Pavement Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	
IRV	North Bay	2000	00.19.2	66	-10.6	0.280	0.220	6
IRV	North Bay	2000	00.19.2	67	-10.6	0.260	0.200	6
IRV	North Bay	2000	00.23.4	69	-9.8	0.270	0.170	15
IRV	North Bay	2000	00.25.8	65	-6.7	0.260	0.130	18
IRV	North Bay	2000	00.25.8	64	-6.7	0.250	0.140	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.290	0.170	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.310	0.200	18
IRV	North Bay	2000	00.25.8	64	-6.7	0.300	0.210	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.310	0.220	18
IRV	Munich	2000	00.52.1	61	-0.3	0.260		18
IRV	Munich	2000	00.52.4	59	0.6	0.280	0.110	18
IRV	Munich	2000	00.52.5	61	1.0	0.320	0.120	18
IRV	Munich	2000	00.53.1	64	3.8	0.320	0.260	5
IRV	Munich	2000	00.53.10	63	3.8	0.340	0.260	5
IRV	Munich	2000	00.53.11	63	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.12	63	3.8	0.340	0.250	5
IRV	Munich	2000	00.53.2	64	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.3	64	3.8	0.320	0.260	5
IRV	Munich	2000	00.53.4	64	3.8	0.310	0.240	5
IRV	Munich	2000	00.53.6	62	3.8	0.320	0.240	5
IRV	Munich	2000	00.53.7	63	3.8	0.310	0.240	5
IRV	Munich	2000	00.53.8	63	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.9	63	3.8	0.350	0.270	5
IRV	North Bay	2001	01.32.3	67	-9.9	0.180	0.100	6
IRV	North Bay	2001	01.32.3	67	-9.5	0.210	0.120	6
IRV	North Bay	2001	01.32.3	66	-9.5	0.210	0.130	6
IRV	North Bay	2001	01.33.1	65	-3.7	0.240	0.140	20
IRV	North Bay	2001	01.33.1	65	-3.7	0.240	0.130	20
IRV	North Bay	2001	01.33.1	65	-3.0	0.240	0.120	20
IRV	North Bay	2002	02.38.5	64	-0.3	0.370	0.340	5
IRV	North Bay	2002	02.38.5	64	-1.5	0.390	0.370	5
IRV	North Bay	2003	03.25.1	64	-9.7	0.230	0.210	10
IRV	North Bay	2003	03.25.1	64		0.210	0.190	10
IRV	North Bay	2003	03.25.1	64	-8.7	0.220	0.200	10
IRV	North Bay	2003	03.25.1	64		0.210	0.190	10
IRV	North Bay	2003	03.25.2	65	-9.2	0.290	0.270	10

Loose Snow on Ice <= 3 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2001	01.31.2	67	-7.8	0.220	0.120	3

Loose Snow on Ice Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2000	00.23.5	67	-8.0	0.300	0.190	15
IRV	North Bay	2000	00.23.5	66	-8.0	0.320	0.220	15
IRV	North Bay	2000	00.23.5	66	-8.0	0.320	0.240	15
IRV	North Bay	2000	00.25.1B	65.7	-9.7	0.180	0.110	5
IRV	North Bay	2001	01.22.1	65	-4.8	0.280	0.190	5
IRV	North Bay	2001	01.22.1	65		0.300	0.210	5
IRV	North Bay	2001	01.22.1	65		0.310	0.220	5
IRV	North Bay	2001	01.24.1	66	-2.6	0.340	0.270	15

Loose Snow on Packed Snow Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2001	01.32.1	67	-14.3	0.200	0.140	5
IRV	North Bay	2001	01.32.1	66	-14.3	0.200	0.140	5
IRV	North Bay	2001	01.32.4	66	-9.1	0.190	0.100	6
IRV	North Bay	2001	01.32.4	66	-8.7	0.200	0.110	6
IRV	North Bay	2001	01.32.4	66	-8.7	0.200	0.100	6

APPENDIX A.4

IRV AND IMAG DATA COMBINED

Bare Ice

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	North Bay	2000	00.18.12	65		0.230	0.140
IRV	North Bay	2000	00.18.12	65		0.250	0.170
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.240	0.160
IRV	North Bay	2000	00.18.12	65		0.230	0.160
IRV	North Bay	2000	00.18.12	66		0.210	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.13	67		0.230	0.170
IRV	North Bay	2000	00.18.13	67		0.210	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.13	67		0.220	0.160
IRV	North Bay	2000	00.18.13	67		0.220	0.140
IRV	North Bay	2000	00.18.13	67		0.220	0.130
IRV	North Bay	2000	00.18.22	38	-21.4	0.240	0.160
IRV	North Bay	2000	00.18.22	64	-21.4	0.240	0.160
IRV	North Bay	2000	00.18.22	85	-21.4	0.200	0.130
IRV	North Bay	2000	00.18.23	42		0.210	0.130
IRV	North Bay	2000	00.18.23	67		0.210	0.120
IRV	North Bay	2000	00.18.23	86		0.210	0.120
IRV	North Bay	2000	00.18.32	68		0.140	0.080
IRV	North Bay	2000	00.18.32	65		0.160	0.080
IRV	North Bay	2000	00.18.32	65		0.160	0.080
IRV	North Bay	2000	00.18.33	67		0.220	0.140
IRV	North Bay	2000	00.18.33	67		0.210	0.130
IRV	North Bay	2000	00.18.33	67		0.210	0.120
IRV	North Bay	2000	00.20.3	64		0.250	0.160
IRV	North Bay	2000	00.20.3	65		0.270	0.180
IRV	North Bay	2000	00.20.3	65		0.230	0.160
IRV	North Bay	2000	00.20.3	65		0.230	0.160
IRV	North Bay	2000	00.20.3	63		0.230	0.160
IRV	North Bay	2000	00.20.3	65		0.240	0.160
IRV	North Bay	2000	00.20.3	63		0.240	0.160
IRV	North Bay	2000	00.20.3	63		0.260	0.180
IRV	North Bay	2000	00.21.2	68		0.220	0.150
IRV	North Bay	2000	00.21.2	68		0.200	0.140
IRV	North Bay	2000	00.21.2	68		0.210	0.150
IRV	North Bay	2000	00.21.2	68		0.210	0.140
IRV	North Bay	2000	00.21.2	68		0.200	0.140
IRV	North Bay	2000	00.21.2	68		0.190	0.130
IRV	North Bay	2000	00.21.2	68		0.190	0.130
IRV	North Bay	2000	00.21.5	67		0.160	0.080
IRV	North Bay	2000	00.21.5	68		0.160	0.090
IRV	North Bay	2000	00.21.5	67		0.160	0.090

IRV	North Bay	2000	00.21.5	67		0.160	0.090
IRV	North Bay	2000	00.21.5	68		0.180	0.110
IRV	North Bay	2000	00.21.5	67		0.180	0.110
IRV	North Bay	2000	00.21.5	67		0.160	0.090
IRV	North Bay	2000	00.23.1	67	-14	0.250	0.130
IRV	North Bay	2000	00.23.1	67	-14	0.250	0.140
IRV	North Bay	2000	00.24.3B	68	-8.80	0.150	0.100
IRV	North Bay	2000	00.24.3B	68	-8.80	0.150	0.100
IRV	North Bay	2000	00.24.3B	68	-8.80	0.150	0.100
IRV	North Bay	2000	00.24.3B	67	-9	0.140	0.090
IRV	North Bay	2000	00.25.2B	66		0.160	0.090
IRV	North Bay	2000	00.25.2B	66		0.160	0.090
IRV	North Bay	2000	00.25.2B	66		0.170	0.090
IRV	North Bay	2000	00.25.31B	61	-24.30	0.240	0.130
IRV	North Bay	2000	00.25.31B	68	-24.30	0.260	0.170
IRV	North Bay	2000	00.25.31B	68	-24.30	0.260	0.150
IRV	North Bay	2000	00.25.31B	68	-24.4	0.270	0.150
IRV	North Bay	2000	00.25.3B	66		0.160	0.090
IRV	North Bay	2000	00.25.3B	66		0.160	0.080
IRV	North Bay	2000	00.25.3B	66		0.150	0.080
IRV	North Bay	2000	00.25.4B	66		0.150	0.080
IRV	North Bay	2000	00.25.4B	66		0.160	0.050
IRV	North Bay	2000	00.25.4B	66		0.150	0.080
IRV	North Bay	2000	00.25.5B	66		0.150	0.080
IRV	North Bay	2000	00.25.5B	66		0.150	0.090
IRV	North Bay	2000	00.25.5B	66		0.160	0.070
IRV	North Bay	2000	00.25.6B	66		0.140	0.060
IRV	North Bay	2000	00.25.6B	66		0.150	0.060
IRV	North Bay	2000	00.25.6B	66		0.140	0.060
IRV	North Bay	2000	00.25.7B	66		0.140	0.060
IRV	North Bay	2000	00.25.7B	66		0.140	0.080
IRV	North Bay	2000	00.27.11B	67		0.220	0.110
IRV	North Bay	2000	00.27.11B	67		0.210	0.110
IRV	North Bay	2000	00.27.11B	67		0.220	0.130
IRV	North Bay	2000	00.27.51B	66	-18	0.190	0.100
IRV	North Bay	2000	00.27.51B	66	-18	0.200	0.120
IRV	North Bay	2000	00.27.51B	66	-18	0.200	0.080
IRV	North Bay	2001	01.23.1	65	-3.2		0.280
IRV	North Bay	2001	01.23.1	65	-3.2		0.270
IRV	North Bay	2001	01.23.1	66	-3.2		0.260
IRV	North Bay	2001	01.23.1	66	-1.9	0.300	0.230
IRV	North Bay	2001	01.23.1	65	-1.9	0.280	0.210
IRV	North Bay	2001	01.23.1	66	-1.9	0.260	0.190
IRV	North Bay	2001	01.24.3	65	-5	0.210	0.120
IRV	North Bay	2001	01.24.3	66		0.200	0.100
IRV	North Bay	2001	01.24.3	66		0.190	0.080
IRV	North Bay	2001	01.24.4	65	-5	0.180	0.080
IRV	North Bay	2001	01.24.4	66		0.200	0.100

IRV	North Bay	2001	01.24.4	66		0.180	0.090
IRV	North Bay	2001	01.24.4	66		0.180	0.090
IRV	North Bay	2001	01.24.4	66		0.190	0.090
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.25.5	68	-12	0.120	0.050
IRV	North Bay	2001	01.26.1	67	-6.30	0.180	0.110
IRV	North Bay	2001	01.26.1	66	-5.5	0.170	0.110
IRV	North Bay	2001	01.26.1	66	-5.5	0.210	0.150
IRV	North Bay	2001	01.26.1	66	-5.40	0.160	0.100
IRV	North Bay	2001	01.26.1	66		0.220	0.160
IRV	North Bay	2001	01.26.3	65	-3.5	0.160	0.080
IRV	North Bay	2001	01.26.3	66		0.150	0.080
IRV	North Bay	2001	01.26.3	66		0.150	0.080
IRV	North Bay	2001	01.26.3	66		0.140	0.070
IRV	North Bay	2001	01.26.3	67		0.140	0.080
IRV	North Bay	2001	01.27.2	65	-12.2	0.130	0.050
IRV	North Bay	2001	01.27.2	65	-12.2	0.110	0.040
IRV	North Bay	2001	01.27.2	65	-12.2	0.100	0.030
IRV	North Bay	2001	01.29.3	68	-3.3	0.150	0.080
IRV	North Bay	2001	01.29.3	67		0.150	0.080
IRV	North Bay	2001	01.29.3	68		0.140	0.070
IRV	North Bay	2001	01.81.1	70	-1	0.160	0.120
IRV	North Bay	2001	01.81.1	65	2.7	0.150	0.110
IRV	North Bay	2001	01.81.1	64		0.130	0.090
IRV	North Bay	2001	01.81.1	62		0.150	0.100
IRV	North Bay	2001	01.81.1	56		0.150	0.110
IRV	North Bay	2001	01.81.1	63		0.150	0.110
IRV	North Bay	2002	02.35.1	65	-17.1	0.110	0.080
IRV	North Bay	2002	02.35.1	65	-13.8	0.100	0.070
IRV	North Bay	2002	02.35.1	65	-14	0.100	0.070
IRV	North Bay	2002	02.35.1	65		0.100	0.070
IRV	North Bay	2002	02.35.1	65		0.100	0.070
IRV	North Bay	2002	02.35.3	64	-15.5	0.130	0.100
IRV	North Bay	2002	02.35.3	64	-15.6	0.110	0.080
IRV	North Bay	2002	02.35.3	64		0.090	0.060
IRV	North Bay	2002	02.35.3	64		0.090	0.050
IRV	North Bay	2002	02.35.3	64		0.080	0.050
IRV	North Bay	2002	02.35.3	64		0.080	0.050
IRV	North Bay	2002	02.35.3	64		0.090	0.060
IRV	North Bay	2002	02.35.5	64	-15.6	0.090	0.060
IRV	North Bay	2002	02.35.5	63	-15.5	0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.050
IRV	North Bay	2002	02.35.5	63		0.080	0.050
IRV	North Bay	2002	02.35.5	63		0.080	0.050
IRV	North Bay	2002	02.35.5	64		0.080	0.040
IRV	North Bay	2002	02.38.3	64	2.60	0.210	0.180

IRV	North Bay	2002	02.38.3	64	2.60	0.190	0.170
IRV	North Bay	2002	02.38.3	64		0.190	0.170
IRV	North Bay	2002	02.38.3	65		0.190	0.170
IRV	North Bay	2002	02.38.3	64		0.190	0.170
IRV	North Bay	2002	02.39.1	64	-13.5	0.300	0.270
IRV	North Bay	2002	02.39.1	64	-12.8	0.290	0.280
IRV	North Bay	2002	02.39.1	65		0.300	0.290
IRV	North Bay	2002	02.39.1	65		0.290	0.270
IRV	North Bay	2002	02.39.1	65		0.280	0.270
IRV	North Bay	2003	03.27.1	65	-26.20	0.210	0.200
IRV	North Bay	2003	03.27.1	65	-23.1	0.200	0.190
IRV	North Bay	2003	03.27.1	65		0.190	0.170
IRV	North Bay	2003	03.27.1	65		0.180	0.160
IRV	North Bay	2003	03.27.1	65		0.160	0.150
IRV	North Bay	2003	03.27.1	65		0.160	0.140
IRV	North Bay	2003	03.28.2	64	-14.6	0.140	0.120
IRV	North Bay	2003	03.28.2	64		0.140	0.120
IRV	North Bay	2003	03.28.2	64	-12.6	0.130	0.120
IRV	North Bay	2003	03.28.2	65		0.130	0.120
IRV	North Bay	2003	03.28.2	64		0.130	0.120
IRV	North Bay	2003	03.29.1	64	-17.6	0.140	0.130
IRV	North Bay	2003	03.29.1	64		0.120	0.110
IRV	North Bay	2003	03.29.1	64	-17.5	0.110	0.100
IRV	North Bay	2003	03.29.1	64		0.110	0.100
IRV	North Bay	2003	03.29.1	64		0.110	0.090
IRV	North Bay	2003	03.30.4	65		0.110	0.100
IRV	North Bay	2003	03.30.4	65		0.100	0.090
IRV	North Bay	2003	03.30.4	65		0.090	0.080
IRV	North Bay	2003	03.30.4	64		0.110	0.090
IRV	New Chitose	2003	03.42.1	66	-5	0.120	0.100
IRV	New Chitose	2003	03.42.1	66	-5.10	0.130	0.120
IRV	New Chitose	2003	03.42.1	67		0.150	0.140
IRV	New Chitose	2003	03.42.1	67		0.150	0.140
IRV	New Chitose	2003	03.42.1	66		0.200	0.190
IRV	New Chitose	2003	03.43.1	64	-4.10	0.160	0.150
IRV	New Chitose	2003	03.43.1	65	-4	0.180	0.170
IRV	New Chitose	2003	03.43.1	66		0.170	0.160
IRV	New Chitose	2003	03.43.1	66		0.180	0.180
IRV	New Chitose	2003	03.43.1	66		0.180	0.180
IRV	New Chitose	2003	03.43.3A	66	-5.3	0.140	0.130
IMAG	North Bay	1996	96.67.3	30	-9.6		0.210
IMAG	North Bay	1996	96.67.3	30	-9.6		0.200
IMAG	North Bay	1996	96.67.3	30	-9.6		0.210
IMAG	North Bay	1996	96.67.3	30	-9.6		0.180
IMAG	North Bay	1996	96.67.3	65	-9.6		0.150
IMAG	North Bay	1996	96.67.3	65	-9.6		0.150
IMAG	North Bay	1996	96.67.3	65	-9.6		0.150
IMAG	North Bay	1996	96.67.3	65	-9.6		0.120

IMAG	North Bay	1996	96.68.2	65	-6.5		0.180
IMAG	North Bay	1996	96.68.2	95	-6.5		0.150
IMAG	North Bay	1997	97.21.3	40	-8		0.130
IMAG	North Bay	1997	97.21.3	40	-8		0.120
IMAG	North Bay	1997	97.21.3	65	-9		0.120
IMAG	North Bay	1997	97.21.3	65	-8.5		0.130
IMAG	North Bay	1997	97.22.1	20	0.3		0.100
IMAG	North Bay	1997	97.22.1	20	0.3		0.100
IMAG	North Bay	1997	97.22.1	30	0.3		0.100
IMAG	North Bay	1997	97.22.1	30	0.3		0.130
IMAG	North Bay	1997	97.22.1	40	0.3		0.140
IMAG	North Bay	1997	97.22.1	40	0.3		0.110
IMAG	North Bay	1997	97.24.2	40	-10.6		0.200
IMAG	North Bay	1997	97.24.2	40	-10.6		0.180
IMAG	North Bay	1997	97.24.2	65	-10.6		0.220
IMAG	North Bay	1997	97.24.2	65	-10.6		0.210
IMAG	North Bay	1997	97.26.5	40	-9		0.170
IMAG	North Bay	1997	97.26.5	40	-9		0.170
IMAG	North Bay	1997	97.26.5	65	-9		0.140
IMAG	North Bay	1997	97.26.5	65	-9		0.150
IMAG	North Bay	1997	97.27.2	40	-15.3		0.180
IMAG	North Bay	1997	97.27.2	40	-15.3		0.190
IMAG	North Bay	1997	97.27.2	65	-15.3		0.140
IMAG	North Bay	1997	97.27.2	65	-15.3		0.150
IMAG	North Bay	1997	97.55.3	40	-10.6		0.100
IMAG	North Bay	1997	97.55.3	40	-10.6		0.070
IMAG	North Bay	1997	97.55.3	65	-10.6		0.080
IMAG	North Bay	1997	97.55.3	65			0.070
IMAG	North Bay	1997	97.57.2	40			0.130
IMAG	North Bay	1997	97.57.2	40			0.130
IMAG	North Bay	1997	97.57.2	65			0.090
IMAG	North Bay	1997	97.57.2	65			0.080
IMAG	North Bay	1997	97.63.3A.2A	40	-1		0.110
IMAG	North Bay	1997	97.63.3A.2A	65	-1		0.090
IMAG	North Bay	1997	97.65.5	40	0		0.120
IMAG	North Bay	1997	97.65.5	40	0		0.120
IMAG	North Bay	1997	97.65.5	65	0		0.120
IMAG	North Bay	1997	97.65.5	65	0		0.100
IMAG	North Bay	1998	98.35.1A	40	-13.9	0.190	0.120
IMAG	North Bay	1998	98.35.1A	40	-13.5	0.170	0.130
IMAG	North Bay	1998	98.35.1A	50	-13.2	0.210	0.140
IMAG	North Bay	1998	98.35.1A	50	-12.9	0.190	0.140
IMAG	North Bay	1998	98.35.1A	65	-12.7	0.220	0.140
IMAG	North Bay	1998	98.35.1A	65	-12.5	0.190	0.150
IMAG	North Bay	1998	98.35.1B	40	-12.5	0.240	0.180
IMAG	North Bay	1998	98.35.1B	40	-12.2	0.230	0.200
IMAG	North Bay	1998	98.35.1B	50	-11.8	0.240	0.170
IMAG	North Bay	1998	98.35.1B	50	-11.5	0.230	0.190

IMAG	North Bay	1998	98.35.1B	65	-11.3	0.230	0.150
IMAG	North Bay	1998	98.35.1B	65	-11.1	0.210	0.160
IMAG	North Bay	1998	98.35.2	50	-6.3	0.190	0.120
IMAG	North Bay	1998	98.35.2	50	-6.3	0.180	0.130
IMAG	North Bay	1998	98.35.2	50	-6.3	0.200	0.130
IMAG	North Bay	1998	98.35.2	50	-6.3	0.180	0.130
IMAG	Norway	1998	98.69.1	42	-8.5	0.110	0.080
IMAG	Norway	1998	98.69.1	48	-8.6	0.120	0.090
IMAG	Norway	1998	98.69.4	44	-3	0.110	0.080
IMAG	Norway	1998	98.69.4	51	-2	0.120	0.090
IMAG	Norway	1998	98.72.1A.1	43	-4.6	0.120	0.090
IMAG	Norway	1998	98.72.1A.1	52	-4	0.110	0.090
IMAG	Norway	1998	98.72.1B.1	42	-2.5	0.140	0.090
IMAG	Norway	1998	98.72.1B.1	51	-1.9	0.140	0.100
IMAG	Norway	1998	98.72.1C.1	42	-0.6	0.130	0.100
IMAG	Norway	1998	98.72.1C.1	53	-0.6	0.130	0.100
IMAG	North Bay	1999	99.20.1A	39	-4.5	0.210	0.170
IMAG	North Bay	1999	99.20.1A	40	-4.4	0.220	0.190
IMAG	North Bay	1999	99.20.1A	38	-3.4	0.180	0.160
IMAG	North Bay	1999	99.20.1A	39	-3.4	0.190	0.170
IMAG	North Bay	1999	99.20.1A	48	-5.4	0.240	0.220
IMAG	North Bay	1999	99.20.1A	48	-6.7	0.220	0.200
IMAG	North Bay	1999	99.20.1A	47	-4.2	0.220	0.190
IMAG	North Bay	1999	99.20.1A	47	-3.8	0.180	0.160
IMAG	North Bay	1999	99.20.1A	65	-6	0.220	0.210
IMAG	North Bay	1999	99.20.1A	63	-6	0.260	0.240
IMAG	North Bay	1999	99.20.1A	63	-4.8	0.250	0.220
IMAG	North Bay	1999	99.20.1A	63	-5	0.250	0.230
IMAG	North Bay	1999	99.20.1A	78	-4.9	0.290	0.260
IMAG	North Bay	1999	99.20.1A	78	-3.4	0.180	0.170
IMAG	North Bay	1999	99.25.1	39	-3.7	0.190	0.150
IMAG	North Bay	1999	99.25.1	39	-3.3	0.190	0.150
IMAG	North Bay	1999	99.25.1	39	-1.5	0.160	0.130
IMAG	North Bay	1999	99.25.1	39	-1.7	0.170	0.140
IMAG	North Bay	1999	99.25.1	48	-4.2	0.200	0.170
IMAG	North Bay	1999	99.25.1	48	-4.2	0.200	0.170
IMAG	North Bay	1999	99.25.1	48	-1.9	0.160	0.140
IMAG	North Bay	1999	99.25.1	48	-2.4	0.160	0.130
IMAG	North Bay	1999	99.25.1	65	-5.3	0.190	0.160
IMAG	North Bay	1999	99.25.1	64	-5.1	0.190	0.170
IMAG	North Bay	1999	99.25.1	63	-3.4	0.180	0.150
IMAG	North Bay	1999	99.25.1	64	-3.3	0.180	0.150
IMAG	North Bay	1999	99.26.1	39	-4.3	0.190	0.140
IMAG	North Bay	1999	99.26.1	38	-4.2	0.200	0.150
IMAG	North Bay	1999	99.26.1	39	-3.5	0.190	0.150
IMAG	North Bay	1999	99.26.1	38	-3.3	0.210	0.160
IMAG	North Bay	1999	99.26.1	49	-4.1	0.190	0.160
IMAG	North Bay	1999	99.26.1	49	-4	0.220	0.180

IMAG	North Bay	1999	99.26.1	49	-3.6	0.210	0.160
IMAG	North Bay	1999	99.26.1	49	-3.6	0.200	0.170
IMAG	North Bay	1999	99.26.1	63	-4.2	0.230	0.190
IMAG	North Bay	1999	99.26.1	63	-4.1	0.210	0.180
IMAG	North Bay	1999	99.26.1	64	-3.8	0.200	0.170
IMAG	North Bay	1999	99.26.1	64	-3.6	0.210	0.180
IMAG	North Bay	1999	99.27.1A	39	-5.6	0.160	0.150
IMAG	North Bay	1999	99.27.1A	39	-5.4	0.140	0.120
IMAG	North Bay	1999	99.27.1A	64	-5.7	0.170	0.140
IMAG	North Bay	1999	99.27.1A	64	-5.5	0.160	0.140
IMAG	Norway	1999	99.61.1	33	-1.1		0.250
IMAG	Norway	1999	99.61.1	36	-0.7	0.190	0.150
IMAG	Norway	1999	99.61.1	35	-0.2	0.200	0.150
IMAG	Norway	1999	99.61.1	48	-0.8	0.290	0.220
IMAG	Norway	1999	99.61.1	48	-0.6	0.220	0.160
IMAG	Norway	1999	99.61.1	49	0	0.210	0.160
IMAG	Norway	1999	99.61.1	64	-0.6	0.230	0.170
IMAG	Norway	1999	99.61.1	63	-0.2	0.240	0.190
IMAG	Norway	1999	99.61.1	63	0	0.210	0.160
IMAG	North Bay	2000	00.18.12	66		0.260	0.140
IMAG	North Bay	2000	00.18.12	66		0.250	0.150
IMAG	North Bay	2000	00.18.12	66		0.240	0.150
IMAG	North Bay	2000	00.18.12	66		0.240	0.160
IMAG	North Bay	2000	00.18.12	66		0.260	0.160
IMAG	North Bay	2000	00.18.12	66		0.250	0.160
IMAG	North Bay	2000	00.18.12	66		0.210	0.120
IMAG	North Bay	2000	00.18.13	67		0.250	0.160
IMAG	North Bay	2000	00.18.13	67		0.240	0.160
IMAG	North Bay	2000	00.18.13	67		0.230	0.150
IMAG	North Bay	2000	00.18.13	67		0.240	0.170
IMAG	North Bay	2000	00.18.13	67		0.210	0.150
IMAG	North Bay	2000	00.18.13	67		0.220	0.150
IMAG	North Bay	2000	00.18.13	67		0.240	0.160
IMAG	North Bay	2000	00.20.3	64		0.280	0.170
IMAG	North Bay	2000	00.20.3	65		0.260	0.170
IMAG	North Bay	2000	00.20.3	66		0.260	0.140
IMAG	North Bay	2000	00.20.3	66		0.250	0.150
IMAG	North Bay	2000	00.20.3	66		0.250	0.150
IMAG	North Bay	2000	00.20.3	66		0.250	0.150
IMAG	North Bay	2000	00.20.3	66		0.250	0.140
IMAG	North Bay	2000	00.20.3	67		0.250	0.160
IMAG	North Bay	2000	00.21.2	66		0.220	0.120
IMAG	North Bay	2000	00.21.2	66		0.210	0.130
IMAG	North Bay	2000	00.21.2	66		0.210	0.120
IMAG	North Bay	2000	00.21.2	66		0.200	0.120
IMAG	North Bay	2000	00.21.2	66		0.200	0.120
IMAG	North Bay	2000	00.21.2	66		0.190	0.120
IMAG	North Bay	2000	00.21.2	66		0.180	0.110

IMAG	North Bay	2000	00.21.5	66		0.170	0.090
IMAG	North Bay	2000	00.21.5	68		0.170	0.090
IMAG	North Bay	2000	00.21.5	66		0.160	0.090
IMAG	North Bay	2000	00.21.5	66		0.170	0.090
IMAG	North Bay	2000	00.21.5	66		0.170	0.090
IMAG	North Bay	2000	00.21.5	65		0.170	0.100
IMAG	North Bay	2000	00.21.5	67		0.160	0.090
IMAG	North Bay	2000	00.23.1	66	-14.6	0.300	0.200
IMAG	North Bay	2000	00.23.1	67	-14.6	0.280	0.190
IMAG	North Bay	2000	00.24.3B	66	-7.7	0.180	0.090
IMAG	North Bay	2000	00.24.3B	67	-7.7	0.200	0.090
IMAG	North Bay	2000	00.24.3B	66	-7.7	0.200	0.090
IMAG	North Bay	2000	00.24.3B	66	-7.7	0.190	0.090
IMAG	North Bay	2000	00.25.31B	66	-23.5	0.280	0.160
IMAG	North Bay	2000	00.25.31B	66	-23.5	0.290	0.180
IMAG	North Bay	2000	00.25.31B	66	-23.5	0.300	0.180
IMAG	North Bay	2000	00.25.31B	66	-23.5	0.290	0.180
IMAG	North Bay	2000	00.25.4B	67		0.170	0.090
IMAG	North Bay	2000	00.25.4B	67		0.180	0.090
IMAG	North Bay	2000	00.25.4B	68		0.170	0.090
IMAG	North Bay	2000	00.25.7B	67		0.170	0.080
IMAG	North Bay	2000	00.25.7B	67		0.170	0.080
IMAG	North Bay	2000	00.27.11B	68		0.280	0.160
IMAG	North Bay	2000	00.27.11B	67		0.260	0.150
IMAG	North Bay	2000	00.27.11B	65		0.230	0.150
IMAG	North Bay	2000	00.27.21B	67		0.260	0.170
IMAG	North Bay	2000	00.27.21B	67		0.250	0.160
IMAG	North Bay	2000	00.27.21B	65		0.250	0.160
IMAG	North Bay	2000	00.27.51B	65	-17.5	0.230	0.140
IMAG	North Bay	2000	00.27.51B	65	-17.5	0.230	0.150
IMAG	North Bay	2000	00.27.51B	64	-17.5	0.220	0.140
IMAG	North Bay	2000	00.18.22	41	-17.5	0.240	0.140
IMAG	North Bay	2000	00.18.22	66	-17.5	0.230	0.140
IMAG	North Bay	2000	00.18.22	93	-17.5	0.200	0.130
IMAG	North Bay	2000	00.18.23	40		0.210	0.140
IMAG	North Bay	2000	00.18.23	66		0.230	0.160
IMAG	North Bay	2000	00.18.23	90		0.230	0.160
IMAG	North Bay	2000	00.18.32	66		0.180	0.080
IMAG	North Bay	2000	00.18.32	66		0.190	0.100
IMAG	North Bay	2000	00.18.32	66			0.090
IMAG	North Bay	2000	00.18.33	66		0.260	0.190
IMAG	North Bay	2000	00.18.33	66		0.240	0.170
IMAG	North Bay	2000	00.18.33	67		0.260	0.190
IMAG	Munich	2001	01.59.1	43	-2.1	0.160	0.130
IMAG	Munich	2001	01.59.1	43	-1.6	0.170	0.130
IMAG	Munich	2001	01.59.1	65	-2.1	0.150	0.170
IMAG	Munich	2001	01.59.1	65	-1.9	0.150	0.160
IMAG	Munich	2001	01.59.1	64	-1.9	0.150	0.160

IMAG	Munich	2001	01.59.1	65	-1.6	0.150	0.150
IMAG	Munich	2001	01.59.6	64		0.190	0.190
IMAG	Munich	2001	01.59.6	65		0.170	0.180
IMAG	Munich	2001	01.60.1	65	-0.1	0.160	0.150
IMAG	Munich	2001	01.60.1	65	-0.1	0.140	0.130
IMAG	Munich	2001	01.60.3	40	-1	0.190	0.170
IMAG	Munich	2001	01.60.3	42	-0.5	0.150	0.130
IMAG	Munich	2001	01.60.3	40	0	0.130	0.100
IMAG	Munich	2001	01.60.3	64	-1	0.170	0.160
IMAG	Munich	2001	01.60.3	65	-0.5	0.190	0.170
IMAG	Munich	2001	01.60.3	64	0	0.130	0.130
IMAG	Munich	2001	01.60.3	88	-1	0.190	0.170
IMAG	Munich	2001	01.60.3	88	-0.5	0.180	0.180
IMAG	Munich	2001	01.60.3	89	0	0.160	0.160

Bare Packed Snow

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	North Bay	2000	00.26.11	67	-20.4	0.270	0.170
IRV	North Bay	2000	00.26.11	67	-20.4	0.280	0.200
IRV	North Bay	2000	00.26.11	67	-20.4	0.280	0.210
IRV	North Bay	2000	00.26.11	67	-20.4	0.270	0.200
IRV	North Bay	2000	00.26.11	66	-20.4	0.270	0.180
IRV	North Bay	2000	00.26.51	65	-16.5	0.230	0.140
IRV	North Bay	2000	00.26.51	65	-16.5	0.240	0.160
IRV	North Bay	2000	00.26.51	65	-16.5	0.230	0.160
IRV	North Bay	2000	00.26.52	65		0.240	0.150
IRV	North Bay	2000	00.26.52	65		0.240	0.160
IRV	North Bay	2000	00.26.52	65		0.240	0.150
IRV	North Bay	2000	00.26.53	65		0.230	0.140
IRV	North Bay	2000	00.26.53	65		0.240	0.160
IRV	North Bay	2000	00.26.53	65		0.240	0.160
IRV	North Bay	2000	00.26.54	65		0.240	0.150
IRV	North Bay	2000	00.26.54	65		0.240	0.170
IRV	North Bay	2000	00.26.54	65		0.260	0.170
IRV	North Bay	2000	00.27.12	67		0.250	0.140
IRV	North Bay	2000	00.27.12	67		0.250	0.160
IRV	North Bay	2000	00.27.12	67		0.250	0.160
IRV	North Bay	2000	00.27.52	66	-17.0	0.250	0.160
IRV	North Bay	2000	00.27.52	67	-17.0	0.240	0.160
IRV	North Bay	2000	00.27.52	66	-17.0	0.240	0.150
IRV	North Bay	2000	00.26.21	41		0.260	0.200
IRV	North Bay	2000	00.26.21	67		0.250	0.180
IRV	North Bay	2000	00.26.21	88		0.250	0.170
IRV	North Bay	2000	00.26.31	68		0.240	0.160
IRV	North Bay	2001	01.26.2	65	-6.4	0.320	0.250
IRV	North Bay	2001	01.26.2	66	-6.4	0.310	0.250
IRV	North Bay	2001	01.26.2	66	-6.4	0.300	0.240
IRV	North Bay	2001	01.26.2	66	-6.4	0.300	0.250
IRV	North Bay	2001	01.26.2	65	-6.4	0.300	0.240
IRV	North Bay	2001	01.27.1	68	-12.2	0.290	0.200
IRV	North Bay	2001	01.27.1	67	-12.2	0.300	0.230
IRV	North Bay	2001	01.27.1	67	-12.5	0.190	0.120
IRV	North Bay	2002	02.35.2	65	-13.8	0.260	0.220
IRV	North Bay	2002	02.35.2	65	-14.0	0.230	0.190
IRV	North Bay	2002	02.35.2	65	-14.0	0.220	0.180
IRV	North Bay	2002	02.35.2	65	-14.0	0.230	0.190
IRV	North Bay	2002	02.35.2	65	-14.0	0.220	0.180
IRV	North Bay	2002	02.35.4	64	-14.0	0.240	0.200
IRV	North Bay	2002	02.35.4	64	-15.6	0.230	0.190
IRV	North Bay	2002	02.35.4	64	-15.0	0.240	0.200
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.190

IRV	North Bay	2002	02.35.4	64	-15.0	0.220	0.190
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.200
IRV	North Bay	2002	02.35.4	64	-15.0	0.230	0.190
IRV	North Bay	2002	02.35.6	64	-15.6	0.260	0.220
IRV	North Bay	2002	02.35.6	64	-15.5	0.260	0.210
IRV	North Bay	2002	02.35.6	64	-15.5	0.240	0.200
IRV	North Bay	2002	02.35.6	65	-15.5	0.250	0.200
IRV	North Bay	2002	02.35.6	65	-15.5	0.250	0.200
IRV	North Bay	2002	02.35.6	64	-15.5	0.270	0.230
IRV	North Bay	2002	02.35.6	64	-15.5	0.240	0.190
IRV	North Bay	2002	02.36.7	63	-6.3	0.230	0.180
IRV	North Bay	2002	02.36.7	63	-6.4	0.210	0.160
IRV	North Bay	2002	02.36.7	63	-6.4	0.230	0.180
IRV	North Bay	2002	02.36.7	63	-6.4	0.210	0.150
IRV	North Bay	2002	02.36.7	64	-6.4	0.210	0.150
IRV	North Bay	2002	02.36.7	64	-6.4	0.200	0.140
IRV	North Bay	2002	02.36.7	64	-6.4	0.240	0.190
IRV	North Bay	2002	02.37.2	67	-0.3	0.220	0.170
IRV	North Bay	2002	02.37.2	67	-3.0	0.210	0.160
IRV	North Bay	2002	02.37.2	67	-3.0	0.230	0.180
IRV	North Bay	2002	02.37.2	65	-3.0	0.260	0.220
IRV	North Bay	2002	02.37.2	65	-3.0	0.240	0.200
IRV	North Bay	2002	02.37.2	65	-3.0	0.230	0.180
IRV	North Bay	2002	02.38.1	65	-1.3	0.210	0.180
IRV	North Bay	2002	02.38.1	66	-1.3	0.210	0.160
IRV	North Bay	2002	02.38.1	66	-1.3	0.200	0.160
IRV	North Bay	2002	02.38.1	66	-1.3	0.220	0.180
IRV	North Bay	2002	02.38.1	65	-1.3	0.200	0.170
IRV	North Bay	2002	02.38.1	65	-1.3	0.190	0.150
IRV	North Bay	2002	02.38.2	65	-1.3	0.230	0.190
IRV	North Bay	2002	02.38.2	66	-1.8	0.220	0.180
IRV	North Bay	2002	02.38.2	66	-1.8	0.210	0.180
IRV	North Bay	2002	02.38.2	64	-1.8	0.220	0.180
IRV	North Bay	2002	02.38.2	64	-1.8	0.220	0.190
IRV	North Bay	2002	02.38.2	65	-1.8	0.210	0.180
IRV	North Bay	2002	02.38.4	64	2.6	0.320	0.280
IRV	North Bay	2002	02.38.4	63	2.6	0.320	0.280
IRV	North Bay	2002	02.38.4	64	2.6	0.310	0.270
IRV	North Bay	2002	02.38.4	64	2.6	0.300	0.260
IRV	North Bay	2002	02.38.4	64	2.6	0.300	0.260
IRV	North Bay	2002	02.39.3	65	-12.8	0.210	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.200	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.190	0.160
IRV	North Bay	2002	02.39.3	65	-12.8	0.200	0.180
IRV	North Bay	2002	02.39.3	65	-12.8	0.190	0.160
IRV	North Bay	2002	02.39.3	64	-12.8	0.210	0.190
IRV	North Bay	2002	02.39.4	65	-12.8	0.280	0.250
IRV	North Bay	2002	02.39.4	64	-12.8	0.260	0.230

IRV	North Bay	2002	02.39.4	65	-12.8	0.270	0.240
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.200
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.190
IRV	North Bay	2002	02.39.4	65	-12.8	0.230	0.200
IRV	North Bay	2003	03.28.1	65	-12.6	0.240	0.210
IRV	North Bay	2003	03.28.1	65	-12.6	0.260	0.240
IRV	North Bay	2003	03.28.1	65	-11.8	0.250	0.230
IRV	North Bay	2003	03.28.1	65	-11.8	0.260	0.240
IRV	North Bay	2003	03.28.1	65	-11.8	0.260	0.240
IRV	North Bay	2003	03.29.2	64	-17.3	0.250	0.230
IRV	North Bay	2003	03.29.2	64	-16.5	0.250	0.240
IRV	North Bay	2003	03.29.2	64	-16.5	0.250	0.240
IRV	North Bay	2003	03.29.2	64	-16.5	0.270	0.250
IRV	North Bay	2003	03.29.2	64	-16.5	0.260	0.250
IRV	North Bay	2003	03.29.6	65	-14.7	0.250	0.230
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	North Bay	2003	03.29.6	65	-14.6	0.230	0.210
IRV	New Chitose	2003	03.42.2	67		0.280	0.270
IRV	New Chitose	2003	03.42.2	65		0.300	0.290
IRV	New Chitose	2003	03.42.2	66		0.300	0.290
IRV	New Chitose	2003	03.42.2	67		0.310	0.300
IRV	New Chitose	2003	03.42.2	65		0.320	0.300
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.260
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.260
IRV	New Chitose	2003	03.43.2	66	-9.4	0.280	0.270
IRV	New Chitose	2003	03.43.2	66	-9.4	0.270	0.270
IRV	New Chitose	2003	03.43.2	66	-9.4	0.300	0.290
IRV	New Chitose	2003	03.44.1	64	-1.6	0.260	0.240
IRV	New Chitose	2003	03.44.1	64	-2.3	0.280	0.250
IRV	New Chitose	2003	03.44.1	64	-2.3	0.250	0.230
IRV	New Chitose	2003	03.44.1	64	-2.3	0.270	0.250
IRV	New Chitose	2003	03.44.1	64	-2.3	0.280	0.260
IMAG	North Bay	1996	96.66.1	30	-14.0		0.260
IMAG	North Bay	1996	96.66.1	30	-14.0		0.270
IMAG	North Bay	1996	96.66.1	30	-14.0		0.260
IMAG	North Bay	1996	96.66.1	65	-17.0		0.230
IMAG	North Bay	1996	96.66.1	30	-15.0		0.250
IMAG	North Bay	1996	96.66.1	90	-13.0		0.200
IMAG	North Bay	1996	96.66.1	90	-13.0		0.190
IMAG	North Bay	1996	96.66.1	90	-13.0		0.170
IMAG	North Bay	1996	96.66.1	90	-13.0		0.220
IMAG	North Bay	1997	97.21.2	40	-12.9		0.110
IMAG	North Bay	1997	97.21.2	40	-12.3		0.110
IMAG	North Bay	1997	97.21.2	65	-12.5		0.100
IMAG	North Bay	1997	97.21.2	65	-12.5		0.100
IMAG	North Bay	1997	97.29.1	40	-23.0		0.170

IMAG	North Bay	1997	97.29.1	40	-23.0		0.170
IMAG	North Bay	1997	97.29.1	65	-23.0		0.140
IMAG	North Bay	1997	97.29.1	65	-23.0		0.140
IMAG	North Bay	1997	97.29.2	40	-17.0		0.190
IMAG	North Bay	1997	97.29.2	40	-17.0		0.190
IMAG	North Bay	1997	97.29.2	65	-17.0		0.150
IMAG	North Bay	1997	97.29.2	65	-17.0		0.150
IMAG	North Bay	1997	97.29.4	40	-16.0		0.170
IMAG	North Bay	1997	97.29.4	40	-16.0		0.180
IMAG	North Bay	1997	97.29.4	65	-16.0		0.150
IMAG	North Bay	1997	97.29.4	65	-16.0		0.140
IMAG	North Bay	1997	97.30.1	40	-21.0		0.190
IMAG	North Bay	1997	97.30.1	40	-21.0		0.180
IMAG	North Bay	1997	97.30.1	65	-21.0		0.180
IMAG	North Bay	1997	97.30.1	65	-21.0		0.170
IMAG	North Bay	1997	97.59.1	40	-9.0		0.200
IMAG	North Bay	1997	97.59.1	40	-9.0		0.250
IMAG	North Bay	1997	97.59.1	65	-9.0		0.200
IMAG	North Bay	1997	97.59.1	65	-9.0		0.210
IMAG	North Bay	1997	97.62.4	40	-2.5		0.210
IMAG	North Bay	1997	97.62.4	40	-2.5		0.180
IMAG	North Bay	1997	97.62.4	65	-2.5		0.140
IMAG	North Bay	1997	97.62.4	65	-2.5		0.130
IMAG	North Bay	1997	97.63.1	40	-7.0		0.200
IMAG	North Bay	1997	97.63.1	40	-7.0		0.240
IMAG	North Bay	1997	97.63.1	65	-7.0		0.220
IMAG	North Bay	1997	97.63.1	65	-7.0		0.200
IMAG	North Bay	1997	97.63.2	40	-2.0		0.190
IMAG	North Bay	1997	97.63.2	40	-2.0		0.190
IMAG	North Bay	1997	97.63.2	65	-2.0		0.210
IMAG	North Bay	1997	97.63.2	65	-2.0		0.200
IMAG	North Bay	1997	97.63.3A.1A	40	-3.3		0.190
IMAG	North Bay	1997	97.63.3A.1A	40	-3.3		0.190
IMAG	North Bay	1997	97.63.3A.1A	65	-3.0		0.190
IMAG	North Bay	1997	97.63.3A.1A	65	-3.0		0.180
IMAG	North Bay	1998	98.30.2C	40	-3.0	0.230	0.150
IMAG	North Bay	1998	98.30.2C	40	-3.0	0.210	0.150
IMAG	North Bay	1998	98.30.2C	40	-3.0	0.230	0.150
IMAG	North Bay	1998	98.30.2C	40	-3.0	0.220	0.160
IMAG	North Bay	1998	98.30.2C	65	-3.0	0.240	0.150
IMAG	North Bay	1998	98.30.2C	65	-3.0	0.190	0.130
IMAG	North Bay	1998	98.30.2C	65	-3.0	0.250	0.150
IMAG	North Bay	1998	98.30.2C	65	-3.0	0.220	0.160
IMAG	North Bay	1998	98.30.2C	90	-3.0	0.240	0.150
IMAG	North Bay	1998	98.30.2C	90	-3.0	0.220	0.150
IMAG	North Bay	1998	98.30.2C	90	-3.0	0.250	0.160
IMAG	North Bay	1998	98.30.2C	90	-3.0	0.230	0.160
IMAG	North Bay	1998	98.31.3C	40	0.0	0.240	0.170

IMAG	North Bay	1998	98.31.3C	40	0.0	0.210	0.160
IMAG	North Bay	1998	98.31.3C	40	0.0	0.240	0.160
IMAG	North Bay	1998	98.31.3C	40	0.0	0.210	0.160
IMAG	North Bay	1998	98.31.3C	65	0.0	0.250	0.170
IMAG	North Bay	1998	98.31.3C	65	0.0	0.220	0.170
IMAG	North Bay	1998	98.31.3C	65	0.0	0.240	0.150
IMAG	North Bay	1998	98.31.3C	65	0.0	0.220	0.160
IMAG	North Bay	1998	98.31.3C	90	0.0	0.250	0.160
IMAG	North Bay	1998	98.31.3C	90	0.0	0.220	0.150
IMAG	North Bay	1998	98.31.3C	90	0.0	0.250	0.150
IMAG	North Bay	1998	98.31.3C	90	0.0	0.220	0.140
IMAG	North Bay	1998	98.40.2	50	-4.2	0.270	0.220
IMAG	North Bay	1998	98.40.2	50	-4.2	0.290	0.220
IMAG	North Bay	1998	98.40.2	90	-4.2	0.280	0.220
IMAG	North Bay	1998	98.40.2	90	-4.2	0.290	0.220
IMAG	North Bay	1998	98.40.2	114	-4.2	0.290	0.230
IMAG	North Bay	1998	98.40.2	109	-4.2	0.270	0.200
IMAG	Norway	1998	98.68.1	42		0.240	0.200
IMAG	Norway	1998	98.68.1	66		0.230	0.180
IMAG	Norway	1998	98.68.1	84		0.230	0.170
IMAG	Norway	1998	98.69.2	41	-12.0	0.230	0.180
IMAG	Norway	1998	98.69.2	64	-12.0	0.230	0.170
IMAG	Norway	1998	98.69.2	87	-12.0	0.210	0.170
IMAG	Norway	1998	98.69.3	42	-10.0	0.210	0.160
IMAG	Norway	1998	98.69.3	68	-10.0	0.210	0.150
IMAG	Norway	1998	98.69.3	89	-10.0	0.210	0.150
IMAG	Norway	1998	98.69.5	42	-8.0	0.170	0.130
IMAG	Norway	1998	98.69.5	68	-8.0	0.180	0.140
IMAG	Norway	1998	98.69.5	87	-8.0	0.190	0.140
IMAG	Norway	1998	98.70.2A	40	-8.0	0.180	0.140
IMAG	Norway	1998	98.70.2A	65	-7.8	0.170	0.130
IMAG	Norway	1998	98.70.2A	90	-7.8	0.180	0.140
IMAG	Norway	1998	98.70.2B	42	-6.9	0.150	0.120
IMAG	Norway	1998	98.70.2B	64	-6.9	0.150	0.120
IMAG	Norway	1998	98.70.2B	87	-6.9	0.150	0.120
IMAG	Norway	1998	98.70.2C	43	-6.9	0.180	0.140
IMAG	Norway	1998	98.70.2C	67	-6.7	0.170	0.130
IMAG	Norway	1998	98.70.2C	88	-6.7	0.170	0.130
IMAG	Norway	1998	98.72.2A.1	42	-4.9	0.230	0.160
IMAG	Norway	1998	98.72.2A.1	65	-4.9	0.200	0.160
IMAG	Norway	1998	98.72.2A.1	87	-4.9	0.210	0.150
IMAG	North Bay	1999	99.22.1	37		0.297	0.243
IMAG	North Bay	1999	99.22.1	38		0.287	0.230
IMAG	North Bay	1999	99.22.1	39		0.303	0.220
IMAG	North Bay	1999	99.22.1	40		0.260	0.180
IMAG	North Bay	1999	99.22.1	48		0.350	0.277
IMAG	North Bay	1999	99.22.1	48		0.323	0.260
IMAG	North Bay	1999	99.22.1	48		0.283	0.203

IMAG	North Bay	1999	99.22.1	48		0.287	0.210
IMAG	North Bay	1999	99.22.1	62		0.373	0.293
IMAG	North Bay	1999	99.22.1	63		0.350	0.283
IMAG	North Bay	1999	99.22.1	64		0.310	0.243
IMAG	North Bay	1999	99.22.1	64		0.363	0.300
IMAG	Sawyer Field	1999	99.32.2A	50		0.290	0.190
IMAG	Sawyer Field	1999	99.34.1	39		0.370	0.290
IMAG	Sawyer Field	1999	99.34.1	39		0.360	0.280
IMAG	Sawyer Field	1999	99.34.1	64		0.360	0.290
IMAG	Sawyer Field	1999	99.34.1	64		0.360	0.290
IMAG	Sawyer Field	1999	99.34.1	89		0.350	0.290
IMAG	Sawyer Field	1999	99.34.1	87		0.360	0.300
IMAG	Sawyer Field	1999	99.35.1	40	-8.5	0.270	0.190
IMAG	Sawyer Field	1999	99.35.1	41	-8.5	0.280	0.200
IMAG	Sawyer Field	1999	99.35.1	40	-8.5	0.230	0.170
IMAG	Sawyer Field	1999	99.35.1	40	-8.5	0.250	0.170
IMAG	Sawyer Field	1999	99.35.1	50	-8.5	0.240	0.180
IMAG	Sawyer Field	1999	99.35.1	50	-8.5	0.270	0.200
IMAG	Sawyer Field	1999	99.35.1	49	-8.5	0.250	0.190
IMAG	Sawyer Field	1999	99.35.1	50	-8.5	0.260	0.200
IMAG	Sawyer Field	1999	99.35.1	64	-8.5	0.300	0.230
IMAG	Sawyer Field	1999	99.35.1	65	-8.5	0.290	0.220
IMAG	Sawyer Field	1999	99.35.1	65	-8.5	0.240	0.190
IMAG	Sawyer Field	1999	99.35.1	65	-8.5	0.240	0.180
IMAG	Sawyer Field	1999	99.35.4	50	-9.0	0.370	0.250
IMAG	Sawyer Field	1999	99.35.2	40	-8.5	0.260	0.170
IMAG	Sawyer Field	1999	99.35.2	40	-8.7	0.280	0.180
IMAG	Sawyer Field	1999	99.35.2	40	-8.9	0.240	0.160
IMAG	Sawyer Field	1999	99.35.2	39	-9.0	0.230	0.140
IMAG	Sawyer Field	1999	99.35.2	49	-8.5	0.280	0.200
IMAG	Sawyer Field	1999	99.35.2	49	-8.7	0.270	0.190
IMAG	Sawyer Field	1999	99.35.2	50	-8.9	0.250	0.170
IMAG	Sawyer Field	1999	99.35.2	54	-9.0	0.230	0.150
IMAG	Sawyer Field	1999	99.35.2	64	-8.5	0.320	0.230
IMAG	Sawyer Field	1999	99.35.2	64	-8.7	0.290	0.210
IMAG	Sawyer Field	1999	99.35.2	65	-8.9	0.270	0.190
IMAG	Sawyer Field	1999	99.35.2	65	-9.0	0.260	0.180
IMAG	Sawyer Field	1999	99.35.5	49		0.320	0.210
IMAG	Sawyer Field	1999	99.36.1A	41	-6.0	0.310	0.230
IMAG	Sawyer Field	1999	99.36.1A	49	-6.0	0.240	0.190
IMAG	Sawyer Field	1999	99.36.1A	65	-6.0	0.300	0.240
IMAG	Norway	1999	99.61.2	40	-1.6	0.370	0.310
IMAG	Norway	1999	99.61.2	42	-1.4	0.350	0.230
IMAG	Norway	1999	99.61.2	42	-1.4	0.370	0.260
IMAG	Norway	1999	99.61.2	42	-0.7	0.360	0.230
IMAG	Norway	1999	99.61.2	63	-1.6	0.350	0.250
IMAG	Norway	1999	99.61.2	64	-1.4	0.340	0.220
IMAG	Norway	1999	99.61.2	64	-1.4	0.350	0.250

IMAG	Norway	1999	99.61.2	65	-0.7	0.360	0.240
IMAG	Norway	1999	99.61.2	80	-1.6	0.330	0.240
IMAG	Norway	1999	99.61.2	85	-1.4	0.340	0.230
IMAG	Norway	1999	99.61.2	87	-1.4	0.340	0.230
IMAG	Norway	1999	99.61.2	89	-0.7	0.330	0.220
IMAG	North Bay	2000	00.26.11	67	-18.0	0.300	0.190
IMAG	North Bay	2000	00.26.11	67	-18.0	0.300	0.200
IMAG	North Bay	2000	00.26.11	66	-18.0	0.300	0.210
IMAG	North Bay	2000	00.26.11	66	-18.0	0.290	0.200
IMAG	North Bay	2000	00.26.11	66	-18.0	0.300	0.200
IMAG	North Bay	2000	00.26.53	66		0.250	0.160
IMAG	North Bay	2000	00.26.53	66		0.260	0.180
IMAG	North Bay	2000	00.26.53	66		0.250	0.180
IMAG	North Bay	2000	00.27.12	65		0.290	0.190
IMAG	North Bay	2000	00.27.12	65		0.290	0.190
IMAG	North Bay	2000	00.27.12	65		0.270	0.200
IMAG	North Bay	2000	00.27.22	67		0.250	0.180
IMAG	North Bay	2000	00.27.22	65		0.250	0.180
IMAG	North Bay	2000	00.27.22	65		0.250	0.180
IMAG	North Bay	2000	00.27.52	64	-19.0	0.270	0.200
IMAG	North Bay	2000	00.27.52	64	-19.0	0.260	0.200
IMAG	North Bay	2000	00.27.52	64	-19.0	0.250	0.190
IMAG	North Bay	2000	00.26.21	39		0.290	0.200
IMAG	North Bay	2000	00.26.21	66		0.260	0.180
IMAG	North Bay	2000	00.26.21	91		0.270	0.180
IMAG	North Bay	2000	00.26.31	65		0.260	0.190

Sanded Ice

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ	
				(km/h)	(°C)	IRV-Force	IRV-Torque
IRV	New Chitose	2003	03.43.3B	66	-1.6	0.390	0.370
IRV	New Chitose	2003	03.43.3B	66		0.370	0.350
IRV	New Chitose	2003	03.43.3B	66		0.390	0.380
IRV	New Chitose	2003	03.43.3B	66			0.400
IRV	New Chitose	2003	03.43.3B	66		0.400	0.390
IMAG	North Bay	1997	97.22.2	40	0.3		0.210
IMAG	North Bay	1997	97.22.2	40	0.3		0.280
IMAG	North Bay	1997	97.22.2	65	1.4		0.170
IMAG	North Bay	1997	97.22.2	65	1.4		0.170
IMAG	Norway	1998	98.72.1C.2	50	-0.6		0.350

Loose Snow on Pavement <= 3 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2001	01.31.2	67	-6.1	0.190	0.110	3
IRV	North Bay	2002	01.31.3	67		0.220	0.120	3
IRV	North Bay	2003	01.31.4	68		0.210	0.110	3
IMAG	North Bay	1998	98.27.1	65	-7.4	0.580	0.470	3
IMAG	North Bay	1998	98.27.1	65	-7.4	0.270	0.160	3
IMAG	North Bay	1998	98.27.1	40	-7.4	0.550	0.420	3
IMAG	North Bay	1998	98.27.1	40	-7.4	0.480	0.350	3
IMAG	Norway	1999	99.62.4	42	-2.3	0.190	0.100	1.5
IMAG	Norway	1999	99.62.4	43	-2.1	0.140		1.5
IMAG	Norway	1999	99.62.4	42	-1.9	0.160		1.5
IMAG	Norway	1999	99.62.4	43	-1.7	0.140		1.5
IMAG	Norway	1999	99.62.4	63	-2.3	0.180		1.5
IMAG	Norway	1999	99.62.4	65	-2.1	0.150		1.5
IMAG	Norway	1999	99.62.4	66	-1.9	0.150		1.5
IMAG	Norway	1999	99.62.4	66	-1.7	0.140		1.5
IMAG	Norway	1999	99.62.4	89	-2.3	0.180		1.5
IMAG	Norway	1999	99.62.4	86	-2.1	0.170		1.5
IMAG	Norway	1999	99.62.4	84	-1.9	0.160		1.5
IMAG	Norway	1999	99.62.4	86	-1.7	0.160		1.5
IMAG	North Bay	2000	00.24.2	66	-7.1	0.680	0.650	0.1
IMAG	North Bay	2000	00.24.2	65	-7.1	0.870	0.830	0.1
IMAG	North Bay	2000	00.24.2	65	-7.1	0.840	0.790	0.1

Loose Snow on Pavement Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2000	00.19.2	66	-10.6	0.280	0.220	6
IRV	North Bay	2000	00.19.2	67	-10.6	0.260	0.200	6
IRV	North Bay	2000	00.23.4	69	-9.8	0.270	0.170	15
IRV	North Bay	2000	00.25.8	65	-6.7	0.260	0.130	18
IRV	North Bay	2000	00.25.8	64	-6.7	0.250	0.140	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.290	0.170	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.310	0.200	18
IRV	North Bay	2000	00.25.8	64	-6.7	0.300	0.210	18
IRV	North Bay	2000	00.25.8	63	-6.7	0.310	0.220	18
IRV	Munich	2000	00.52.1	61	-0.3	0.260		18
IRV	Munich	2000	00.52.4	59	0.6	0.280	0.110	18
IRV	Munich	2000	00.52.5	61	1.0	0.320	0.120	18
IRV	Munich	2000	00.53.1	64	3.8	0.320	0.260	5
IRV	Munich	2000	00.53.10	63	3.8	0.340	0.260	5
IRV	Munich	2000	00.53.11	63	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.12	63	3.8	0.340	0.250	5
IRV	Munich	2000	00.53.2	64	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.3	64	3.8	0.320	0.260	5
IRV	Munich	2000	00.53.4	64	3.8	0.310	0.240	5
IRV	Munich	2000	00.53.6	62	3.8	0.320	0.240	5
IRV	Munich	2000	00.53.7	63	3.8	0.310	0.240	5
IRV	Munich	2000	00.53.8	63	3.8	0.330	0.260	5
IRV	Munich	2000	00.53.9	63	3.8	0.350	0.270	5
IRV	North Bay	2001	01.32.3	67	-9.9	0.180	0.100	6
IRV	North Bay	2001	01.32.3	67	-9.5	0.210	0.120	6
IRV	North Bay	2001	01.32.3	66	-9.5	0.210	0.130	6
IRV	North Bay	2001	01.33.1	65	-3.7	0.240	0.140	20
IRV	North Bay	2001	01.33.1	65	-3.7	0.240	0.130	20
IRV	North Bay	2001	01.33.1	65	-3.0	0.240	0.120	20
IRV	North Bay	2002	02.38.5	64	-0.3	0.370	0.340	5
IRV	North Bay	2002	02.38.5	64	-1.5	0.390	0.370	5
IRV	North Bay	2003	03.25.1	64	-9.7	0.230	0.210	10
IRV	North Bay	2003	03.25.1	64		0.210	0.190	10
IRV	North Bay	2003	03.25.1	64	-8.7	0.220	0.200	10
IRV	North Bay	2003	03.25.1	64		0.210	0.190	10
IRV	North Bay	2003	03.25.2	65	-9.2	0.290	0.270	10
IMAG	North Bay	1996	96.66.2	65	-13.0		0.200	6.5
IMAG	North Bay	1996	96.66.2	90	-13.0		0.180	6.5
IMAG	North Bay	1997	97.25.4	40	-8.6		0.110	25
IMAG	North Bay	1997	97.25.4	40	-8.6		0.110	25
IMAG	North Bay	1997	97.28.1	40	-21.0		0.210	6
IMAG	North Bay	1997	97.28.1	40	-21.0		0.230	6
IMAG	North Bay	1997	97.28.1	65	-21.0		0.170	6
IMAG	North Bay	1997	97.28.1	65	-21.0		0.140	6

IMAG	North Bay	1997	97.29.3	40			0.120	22
IMAG	North Bay	1997	97.29.3	40			0.110	22
IMAG	North Bay	1997	97.29.3	65			0.130	22
IMAG	North Bay	1997	97.62.5	40	-4.2		0.110	13
IMAG	North Bay	1997	97.62.5	65	-4.2		0.160	13
IMAG	North Bay	1997	97.62.6	40	-3.9		0.120	16
IMAG	North Bay	1997	97.62.6	65	-3.9		0.100	16
IMAG	North Bay	1998	98.28.2	40		0.150		12
IMAG	North Bay	1998	98.28.2	40		0.160		12
IMAG	North Bay	1998	98.28.2	65		0.160		12
IMAG	North Bay	1998	98.28.2	65		0.160		12
IMAG	Norway	1999	99.62.2A	42	-3.8	0.230	0.150	10
IMAG	Norway	1999	99.62.2A	65	-3.8	0.230	0.130	10
IMAG	Norway	1999	99.62.2A	87	-3.8	0.220	0.130	10
IMAG	Norway	1999	99.62.3	43	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	42	-3.0	0.200	0.100	25
IMAG	Norway	1999	99.62.3	42	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	42	-3.0	0.170	0.100	25
IMAG	Norway	1999	99.62.3	66	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	65	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	65	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	63	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	89	-3.0	0.210	0.120	25
IMAG	Norway	1999	99.62.3	89	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	88	-3.0	0.200	0.110	25
IMAG	Norway	1999	99.62.3	89	-3.0	0.200	0.120	25
IMAG	North Bay	2000	00.19.2	65	-8.9	0.260	0.180	6
IMAG	North Bay	2000	00.19.2	67	-8.9	0.260	0.200	6
IMAG	North Bay	2000	00.19.2	66	-8.9	0.250	0.170	6
IMAG	North Bay	2000	00.19.2	67	-8.9	0.250	0.180	6
IMAG	North Bay	2000	00.19.2	67	-8.9	0.270	0.190	6
IMAG	North Bay	2000	00.19.2	67	-8.9	0.280	0.200	6
IMAG	North Bay	2000	00.23.4	67		0.300	0.190	15
IMAG	North Bay	2000	00.23.4	66		0.290	0.180	15
IMAG	North Bay	2000	00.23.4	67		0.290	0.190	15
IMAG	North Bay	2000	00.25.8	67	-5.0	0.250	0.130	18
IMAG	North Bay	2000	00.25.8	67	-5.0	0.220	0.140	18
IMAG	North Bay	2000	00.25.8	67	-5.0	0.320	0.200	18
IMAG	North Bay	2000	00.25.8	67	-5.0	0.320	0.220	18
IMAG	North Bay	2000	00.25.8	67	-5.0	0.350	0.250	18
IMAG	North Bay	2000	00.25.8	67	-5.0	0.350	0.260	18
IMAG	Munich	2000	00.52.1	63	0.0	0.290	0.100	18
IMAG	Munich	2000	00.52.1	63	0.0	0.290	0.130	18
IMAG	Munich	2000	00.52.1	65	0.0	0.290	0.140	18
IMAG	Munich	2000	00.53.1	64	-3.8	0.360	0.240	5
IMAG	Munich	2001	01.61.2	63	-1.5	0.380	0.300	24
IMAG	Munich	2001	01.61.2	62	-1.5	0.360	0.300	24
IMAG	Munich	2001	01.61.2	65	-1.5	0.350	0.280	24

IMAG	Munich	2001	01.61.2	64	-1.5	0.370	0.270	24
IMAG	Munich	2001	01.61.2	64	-1.5	0.370	0.290	24
IMAG	Munich	2001	01.61.2	65	-1.5	0.350	0.290	24
IMAG	Munich	2001	01.61.2	64	-1.5	0.390	0.300	24
IMAG	Munich	2001	01.61.2	65	-1.5	0.370	0.300	24
IMAG	Munich	2001	01.61.2	66	-1.5	0.310	0.240	24
IMAG	Munich	2001	01.61.2	65	-1.5	0.340	0.270	24
IMAG	Munich	2001	01.61.2	65	-1.5	0.360	0.310	24
IMAG	Munich	2001	01.61.3	65	0.0	0.230	0.180	8
IMAG	Munich	2001	01.61.3	64	0.0	0.320	0.240	8
IMAG	Munich	2001	01.61.3	61	0.0	0.160	0.100	8
IMAG	Munich	2001	01.61.3	64	0.0	0.240	0.180	8
IMAG	Munich	2001	01.61.4	40	0.0	0.340	0.300	8
IMAG	Munich	2001	01.61.4	66	0.0	0.300	0.210	8
IMAG	Munich	2001	01.61.4	90	0.0	0.190	0.120	8

Loose Snow on Ice <= 3 mm

Device	**Site**	**Year**	**Test no.**	**Speed**	**Temp.**	**Avg. μ**		**Depth**
				(km/h)	**(°C)**	**IRV-Force**	**IRV-Torque**	**(mm)**
IRV	North Bay	2001	01.31.2	67	-7.8	0.220	0.120	3

Loose Snow on Ice Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. μ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IMAG	North Bay	1997	97.28.5	40	-12.5		0.200	5
IMAG	North Bay	1997	97.28.5	40	-12.5		0.200	5
IMAG	North Bay	1997	97.28.5	65	-12.5		0.190	5
IMAG	North Bay	1997	97.28.5	65	-12.5		0.150	5
IMAG	North Bay	1997	97.55.1	40	-20.2		0.100	25
IMAG	North Bay	1997	97.55.1	40	-20.2		0.160	25
IMAG	North Bay	1997	97.55.1	65	-20.2		0.120	25
IMAG	North Bay	1997	97.55.1	65	-20.2		0.150	25
IMAG	North Bay	1997	97.56.1	40	-15.6		0.230	10
IMAG	North Bay	1997	97.56.1	40	-15.6		0.260	10
IMAG	North Bay	1997	97.56.1	65	-15.6		0.230	10
IMAG	North Bay	1997	97.56.1	65	-15.6		0.250	10
IMAG	North Bay	1997	97.56.5	40			0.190	16
IMAG	North Bay	1997	97.56.5	40			0.190	16
IMAG	North Bay	1997	97.56.5	65			0.160	16
IMAG	North Bay	1997	97.56.5	65			0.180	16
IMAG	North Bay	1999	99.19.2	39	-1.0	0.200	0.160	5
IMAG	North Bay	1999	99.19.2	39	-1.0	0.200	0.160	5
IMAG	North Bay	1999	99.19.2	40	-1.0	0.190	0.160	5
IMAG	North Bay	1999	99.19.2	39	-1.0	0.180	0.140	5
IMAG	North Bay	1999	99.19.2	50	-1.0	0.250	0.210	5
IMAG	North Bay	1999	99.19.2	49	-1.0	0.220	0.180	5
IMAG	North Bay	1999	99.19.2	49	-1.0	0.190	0.160	5
IMAG	North Bay	1999	99.19.2	49	-1.0	0.180	0.160	5
IMAG	North Bay	1999	99.19.2	63	-1.0	0.290	0.240	5
IMAG	North Bay	1999	99.19.2	64	-1.0	0.270	0.230	5
IMAG	North Bay	1999	99.19.2	64	-1.0	0.210	0.180	5
IMAG	North Bay	1999	99.19.2	64	-1.0	0.210	0.180	5
IMAG	North Bay	1999	99.20.1B	39	-6.7	0.220	0.190	5
IMAG	North Bay	1999	99.20.1B	39	-6.7	0.180	0.150	5
IMAG	North Bay	1999	99.20.1B	38	-3.4	0.170	0.150	5
IMAG	North Bay	1999	99.20.1B	39	-3.4	0.160	0.140	5
IMAG	North Bay	1999	99.20.1B	48	-6.7	0.240	0.210	5
IMAG	North Bay	1999	99.20.1B	48	-6.7	0.220	0.200	5
IMAG	North Bay	1999	99.20.1B	47	-3.4	0.180	0.160	5
IMAG	North Bay	1999	99.20.1B	47	-3.4	0.170	0.150	5
IMAG	North Bay	1999	99.20.1B	64	-6.7	0.250	0.220	5
IMAG	North Bay	1999	99.20.1B	63	-6.7	0.200	0.190	5
IMAG	North Bay	1999	99.20.1B	63	-3.4	0.160	0.140	5
IMAG	North Bay	1999	99.20.1B	62	-3.4	0.180	0.170	5
IMAG	North Bay	1999	99.20.1B	78	-4.4	0.190	0.160	5
IMAG	North Bay	1999	99.20.1B	78	-3.6	0.160	0.150	5
IMAG	North Bay	2000	00.23.5	66	-14.5	0.320	0.220	15
IMAG	North Bay	2000	00.23.5	67	-14.5	0.330	0.230	15

IMAG	North Bay	2000	00.23.5	67	-14.5	0.330	0.230	15
IMAG	North Bay	2000	00.25.1B	67.3	-13.0	0.220	0.110	5
IRV	North Bay	2000	00.23.5	67	-8.0	0.300	0.190	15
IRV	North Bay	2000	00.23.5	66	-8.0	0.320	0.220	15
IRV	North Bay	2000	00.23.5	66	-8.0	0.320	0.240	15
IRV	North Bay	2000	00.25.1B	65.7	-9.7	0.180	0.110	5
IRV	North Bay	2001	01.22.1	65	-4.8	0.280	0.190	5
IRV	North Bay	2001	01.22.1	65		0.300	0.210	5
IRV	North Bay	2001	01.22.1	65		0.310	0.220	5
IRV	North Bay	2001	01.24.1	66	-2.6	0.340	0.270	15

Loose Snow on Packed Snow Between 3 mm and 25 mm

Device	Site	Year	Test no.	Speed	Temp.	Avg. µ		Depth
				(km/h)	(°C)	IRV-Force	IRV-Torque	(mm)
IRV	North Bay	2001	01.32.1	67	-14.3	0.200	0.140	5
IRV	North Bay	2001	01.32.1	66	-14.3	0.200	0.140	5
IRV	North Bay	2001	01.32.4	66	-9.1	0.190	0.100	6
IRV	North Bay	2001	01.32.4	66	-8.7	0.200	0.110	6
IRV	North Bay	2001	01.32.4	66	-8.7	0.200	0.100	6
IMAG	North Bay	1998	98.37.3	40	-5.1	0.240	0.180	8
IMAG	North Bay	1998	98.37.3	68	-5.1	0.250	0.180	8
IMAG	North Bay	1998	98.37.3	68	-5.1	0.230	0.180	8
IMAG	North Bay	1998	98.37.3	68	-5.1	0.220	0.180	8
IMAG	North Bay	1998	98.37.3	85	-5.1	0.260	0.180	8
IMAG	North Bay	1998	98.37.3	90	-5.1	0.260	0.170	8

APPENDIX B

HISTOGRAMS OF RAW DATA

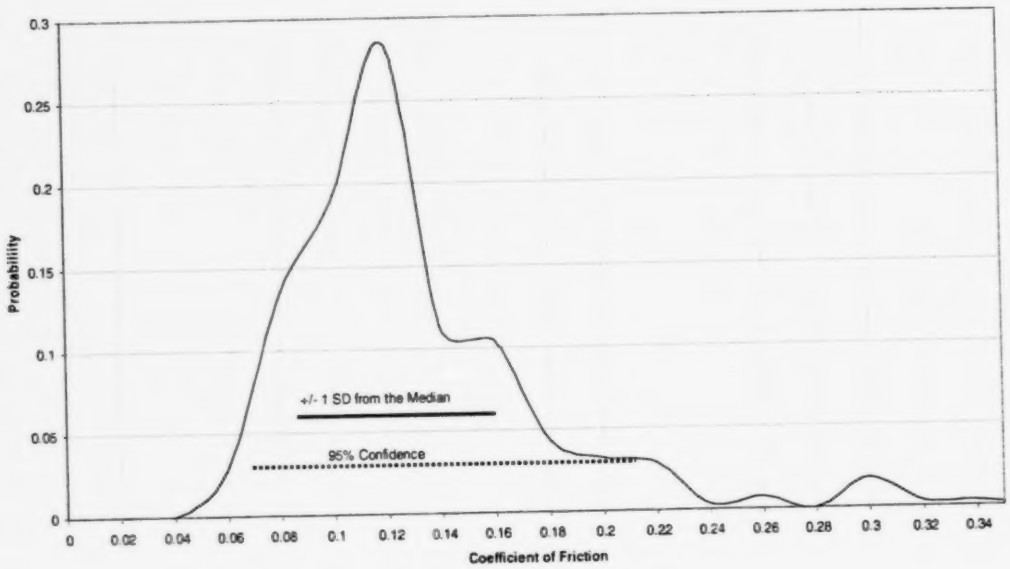
Contents:

Appendix B.1 ERD Histograms
Appendix B.2 TC SFT Histograms
Appendix B.3 IRV Histograms
Appendix B.4 Histograms for IRV and IMAG Combined

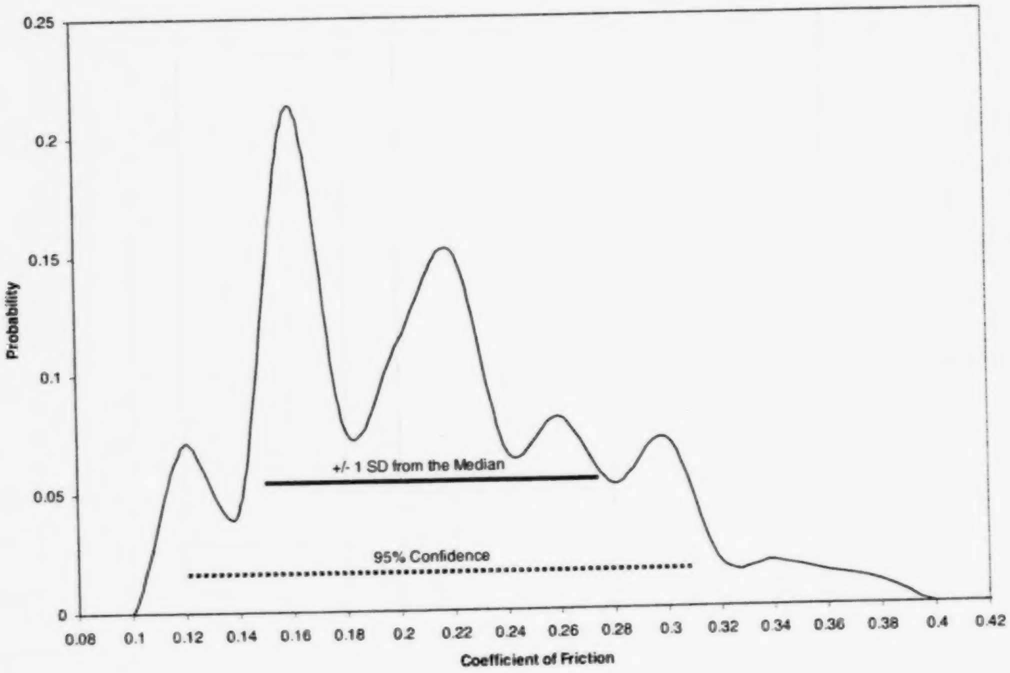
APPENDIX B.1

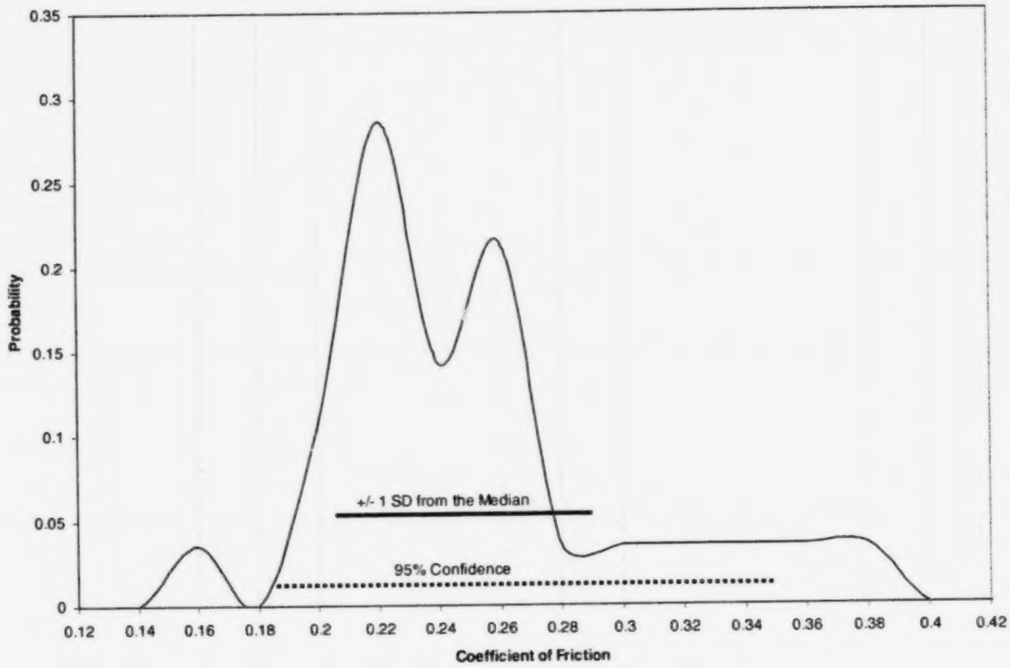
ERD HISTOGRAMS

Probability Distribution for ERD on Bare Ice

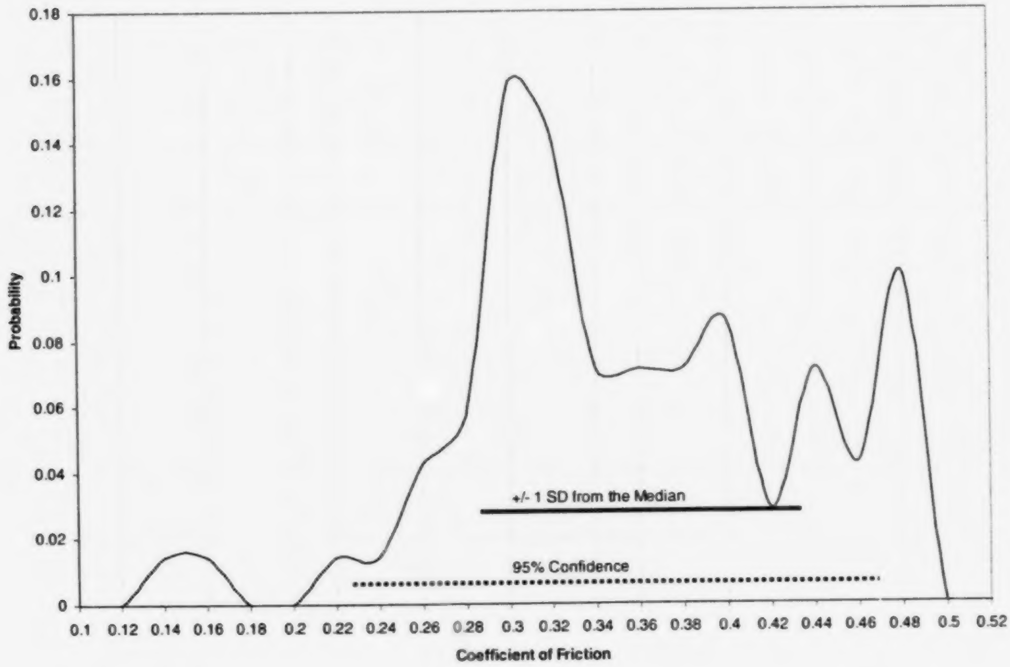


Probability Distribution for ERD on Bare Packed Snow



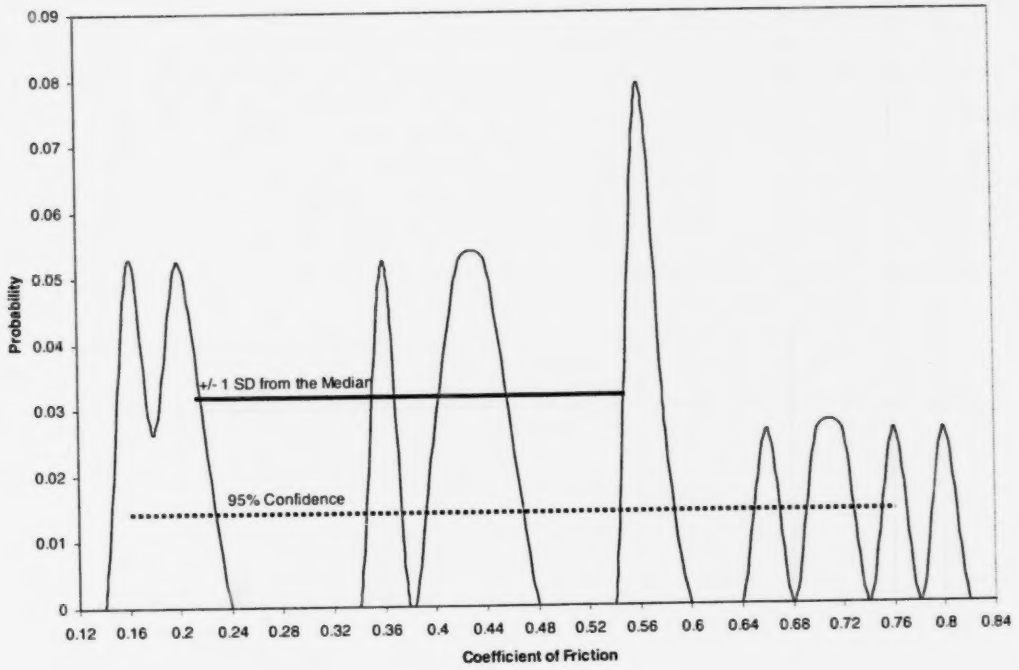


Probability Distribution for ERD on Sanded Ice

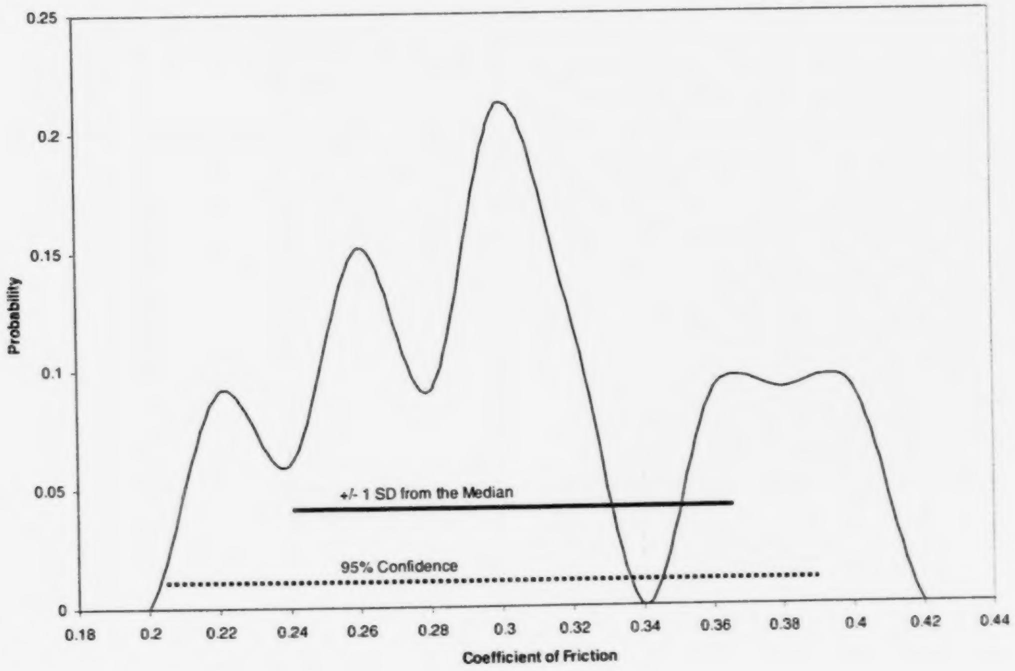


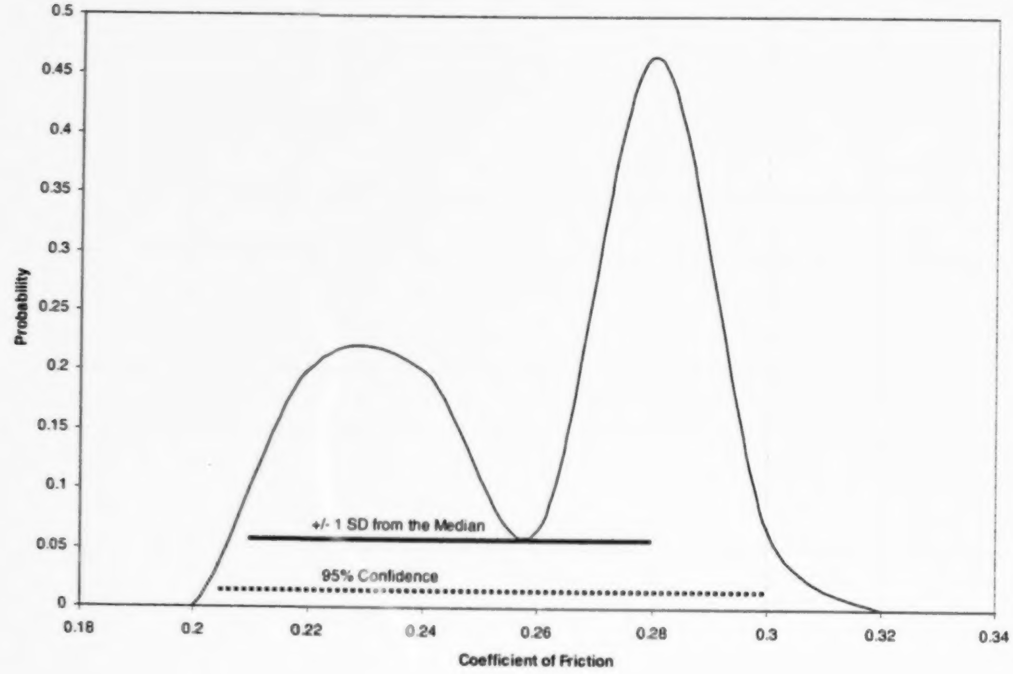
Probability Distribution for ERD on Sanded Packed Snow

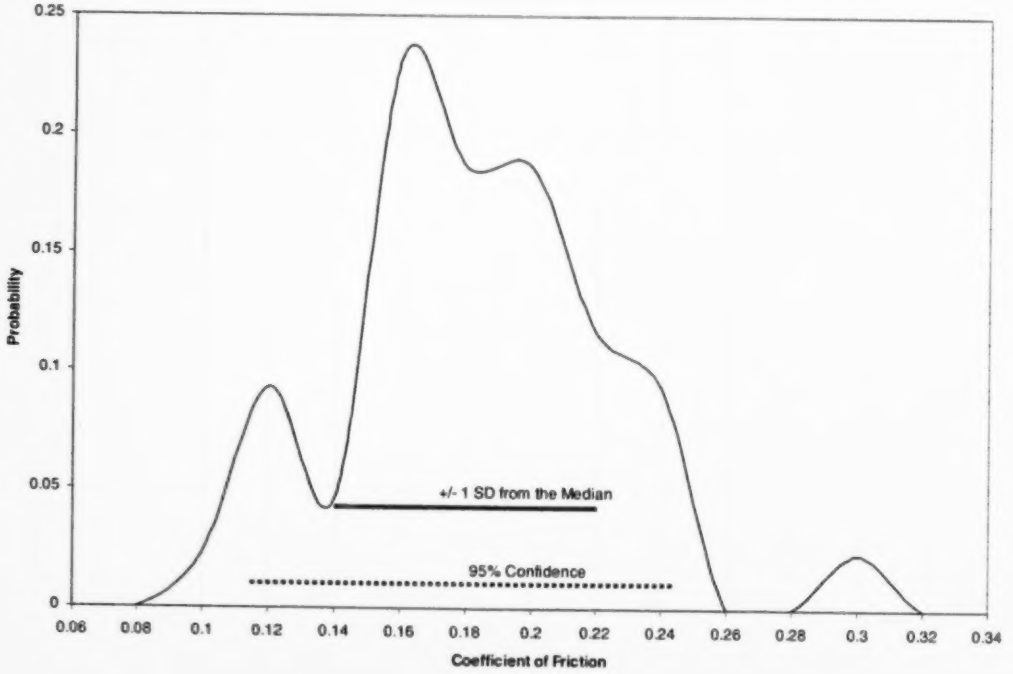
Probability Distribution for ERD on Loose Snow on Pavement Less Than 3 mm Deep

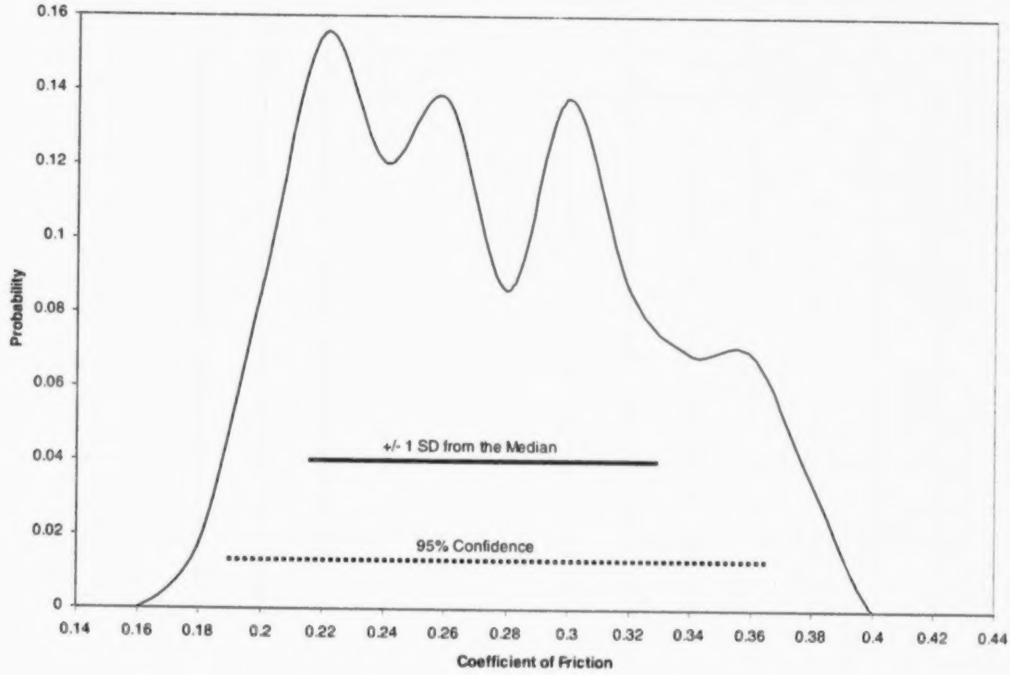


Probability Distribution for ERD on Loose Snow on Pavement Between 3 and 25 mm Deep

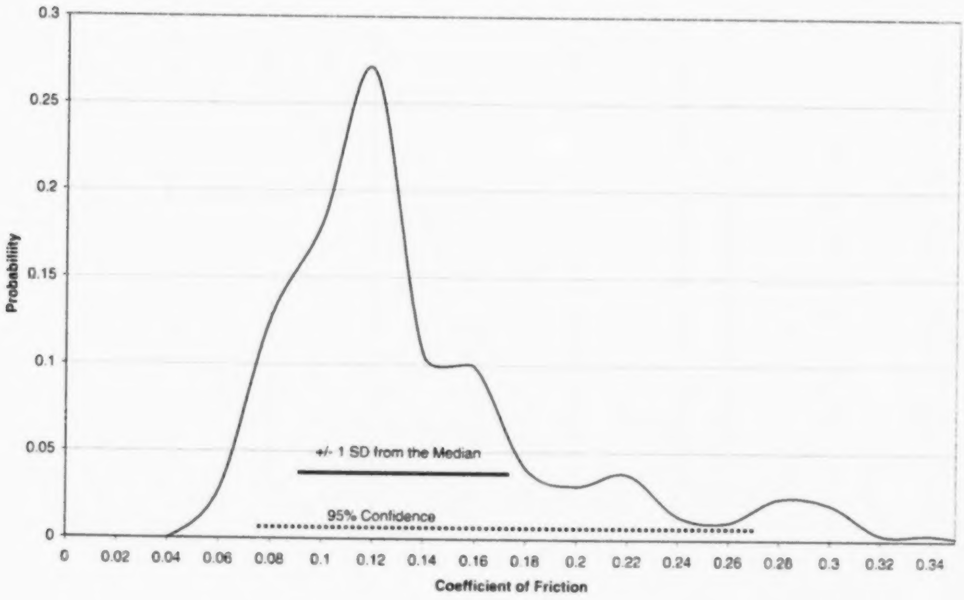



Probability Distribution for ERD on Loose Snow on Ice <= 3 mm Deep


Probability Distribution for ERD on Loose Snow on Ice Between 3 and 25 mm Deep



Probability Distribution for ERD on Loose Snow and on Packed Snow Between 3 and 25 mm Deep

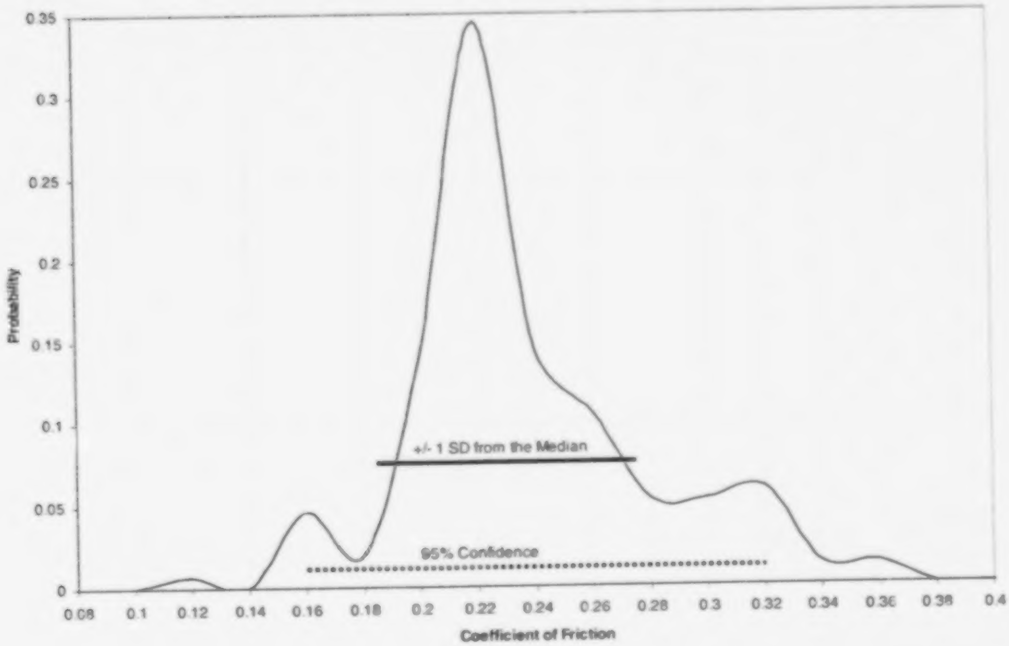


Probability Distribution for ERD on Bare Ice and on Loose Snow on Ice <= 3 mm Combined

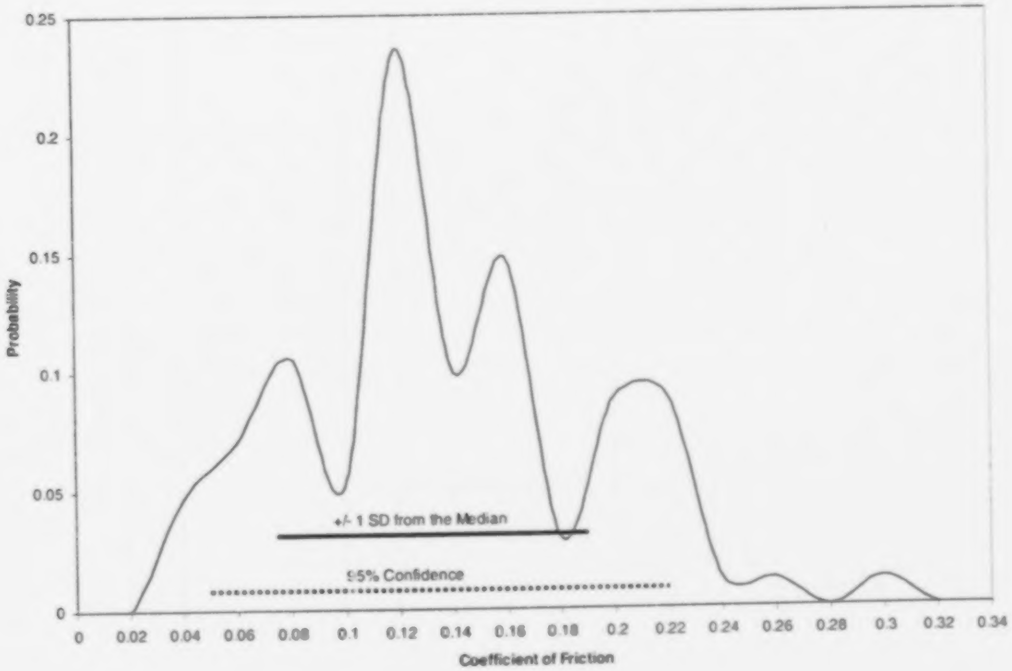
APPENDIX B.2

TC SFT HISTOGRAMS

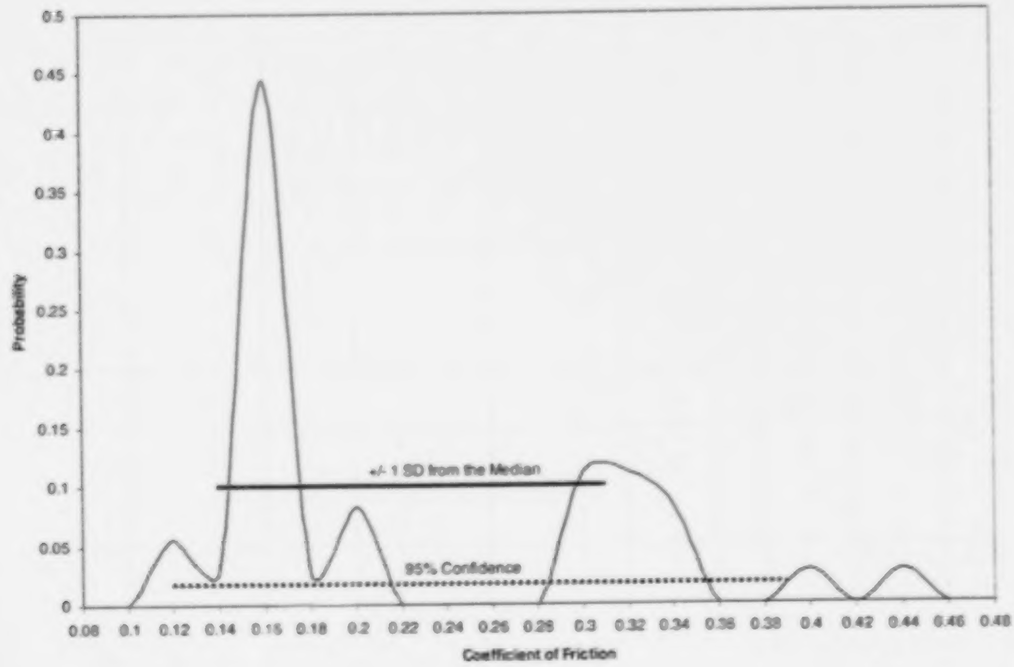
Probability Distribution for TC SFT on Bare Packed Snow



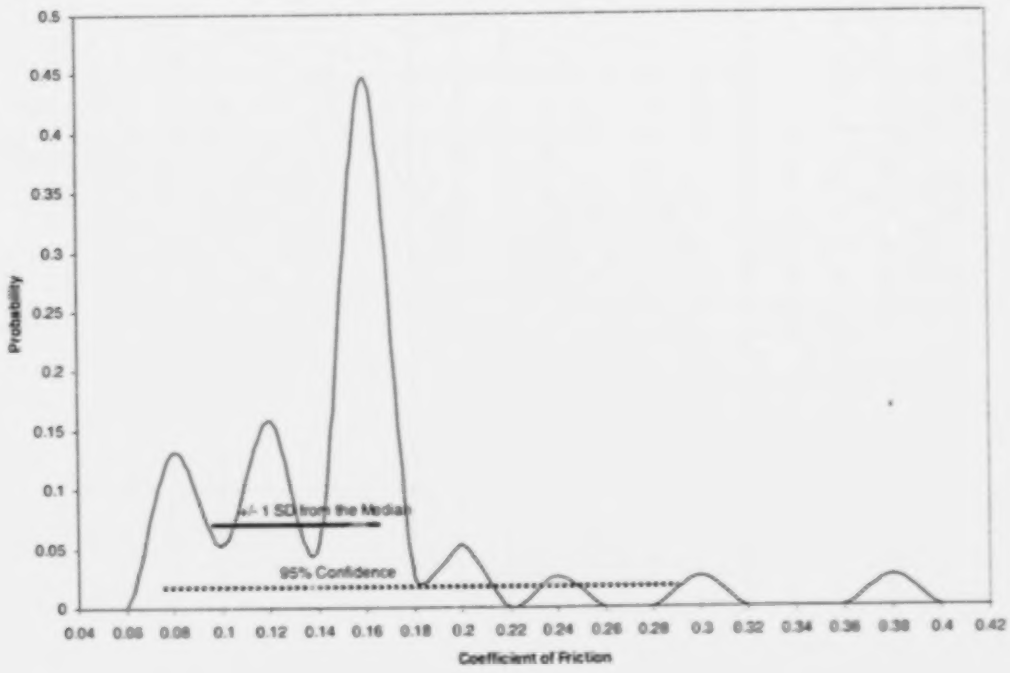
Probability Distribution for TC SFT on Bare Ice



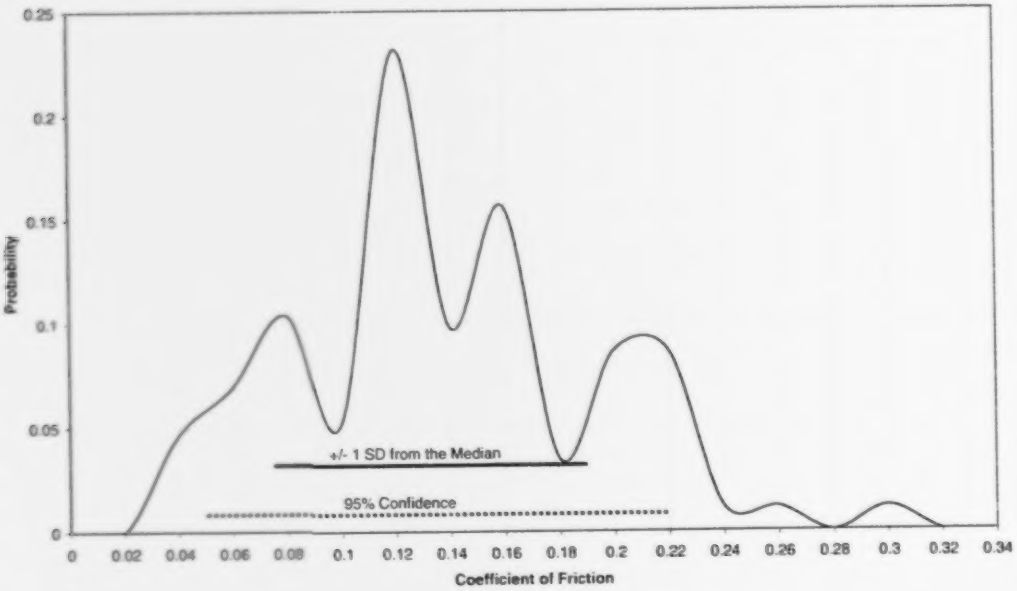
Probability Distribution for TC SFT on Loose Snow on Pavement Between 3 and 25 mm Deep



Probability Distribution for TC SFT on Loose Snow on Ice Between 3 and 25 mm Deep



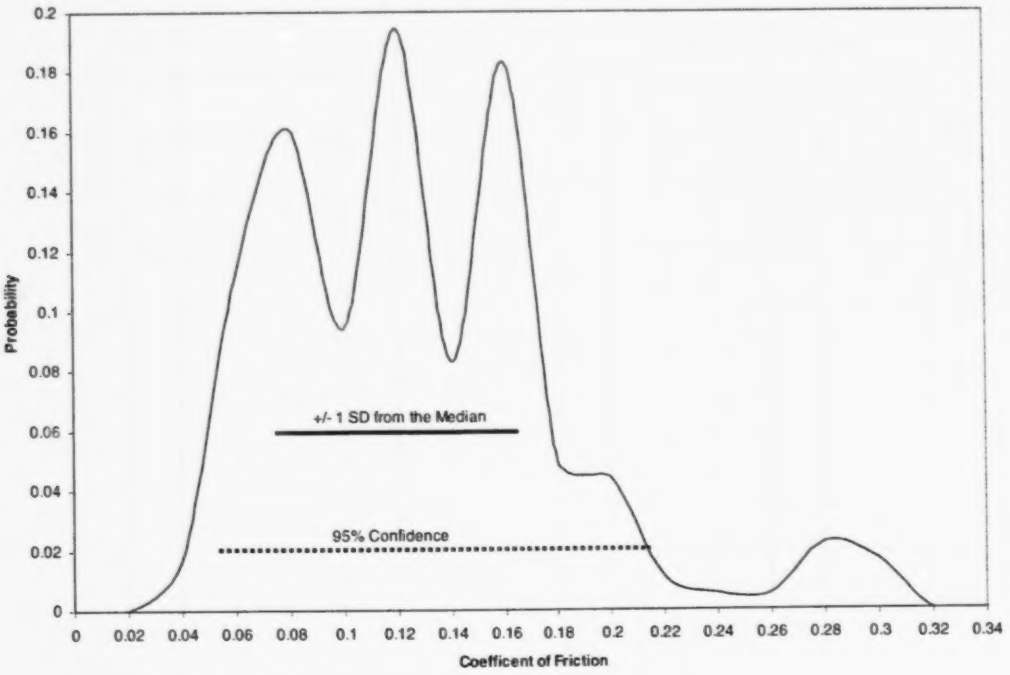
Probability Distribution for TC SFT on Bare Ice and on Loose Snow on Ice <= 3 mm Deep Combined



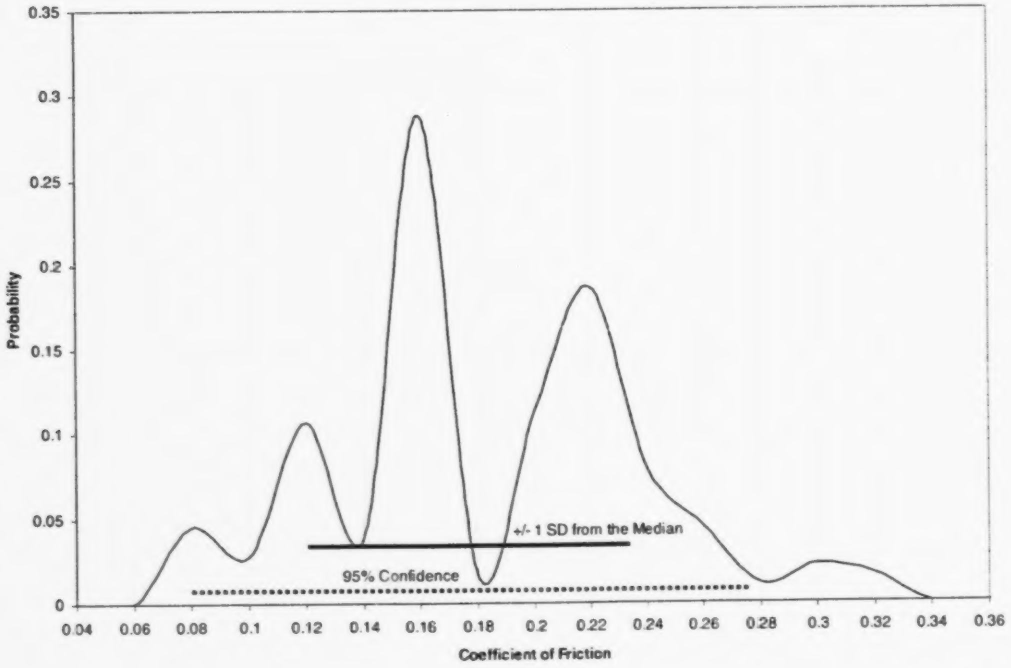
APPENDIX B.3

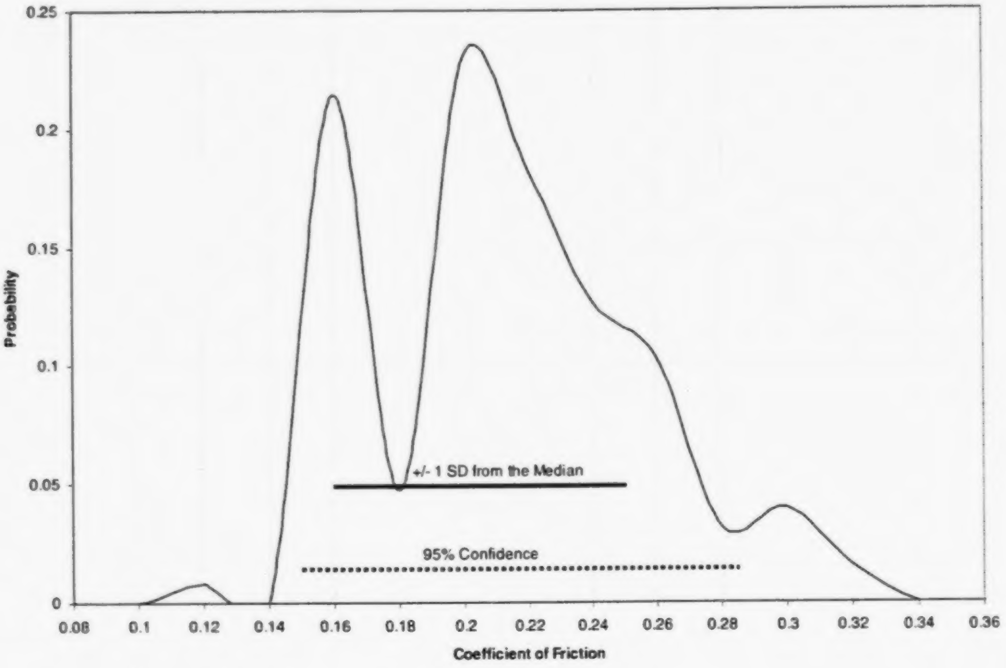
IRV HISTOGRAMS

Probability Distribution for IRV-Torque on Bare Ice

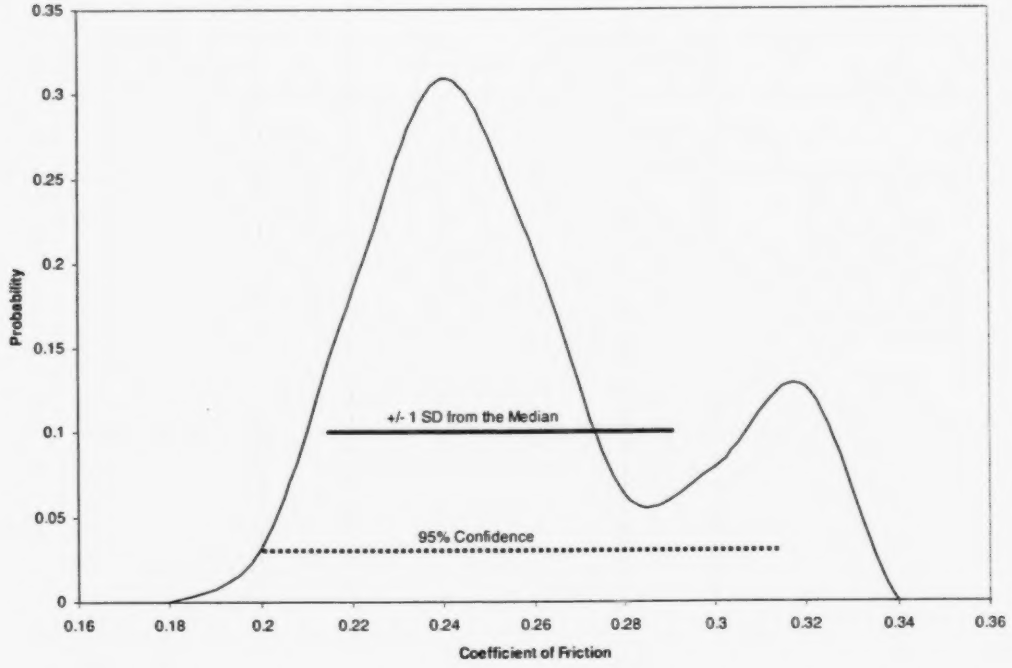


Probability Distribution for IRV-Force on Bare Ice



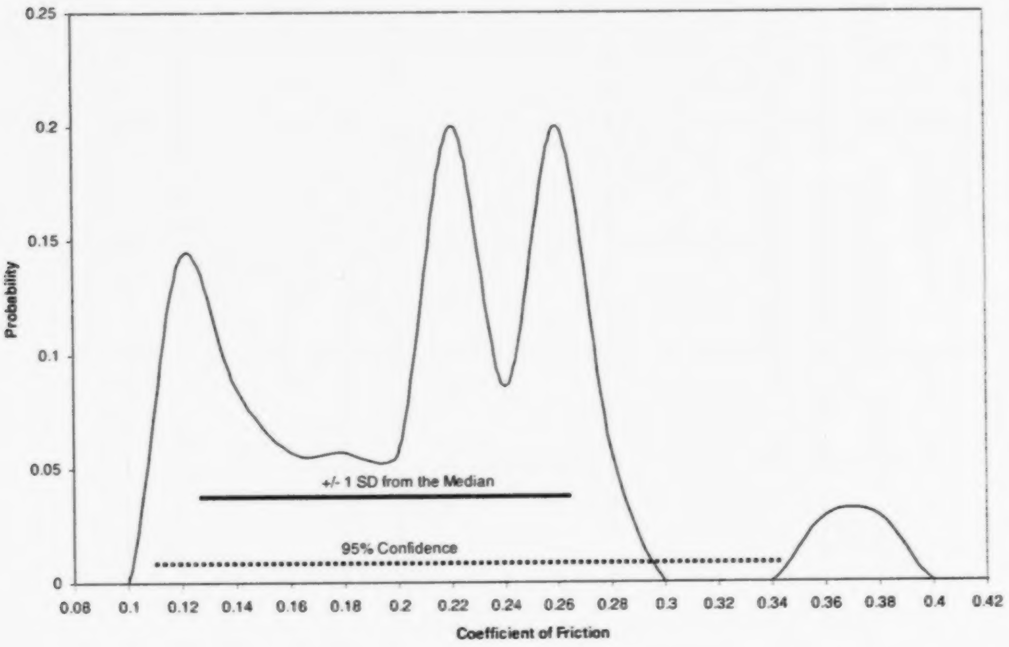


Probability Distribution for IRV-Torque on Bare Packed Snow

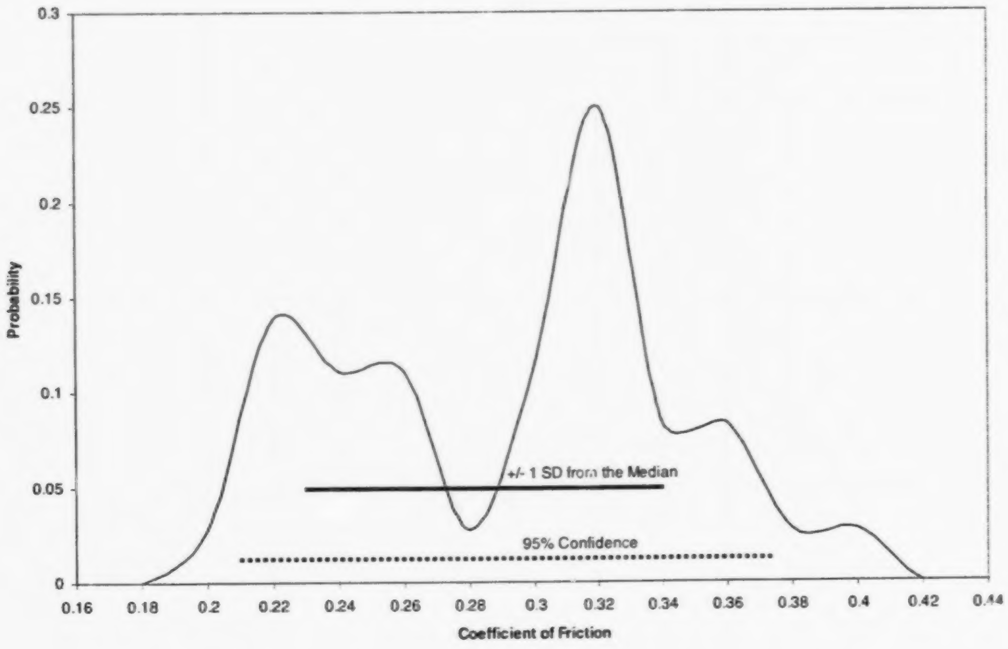


Probability Distribution for IRV-Force on Bare Packed Snow

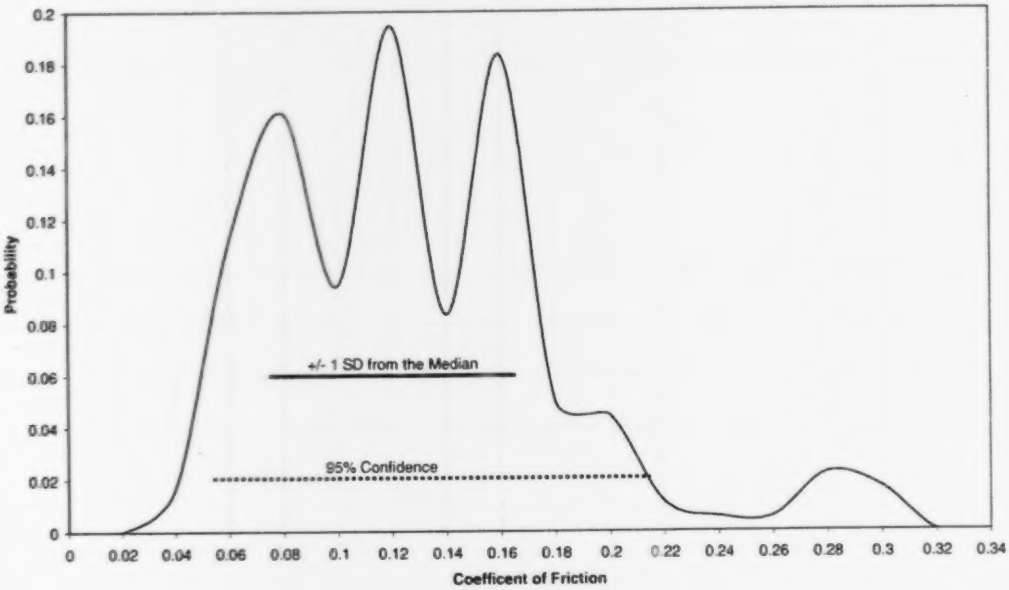
Probability Distribution for IRV-Torque on Loose Snow on Pavement Between 3 and 25 mm Deep



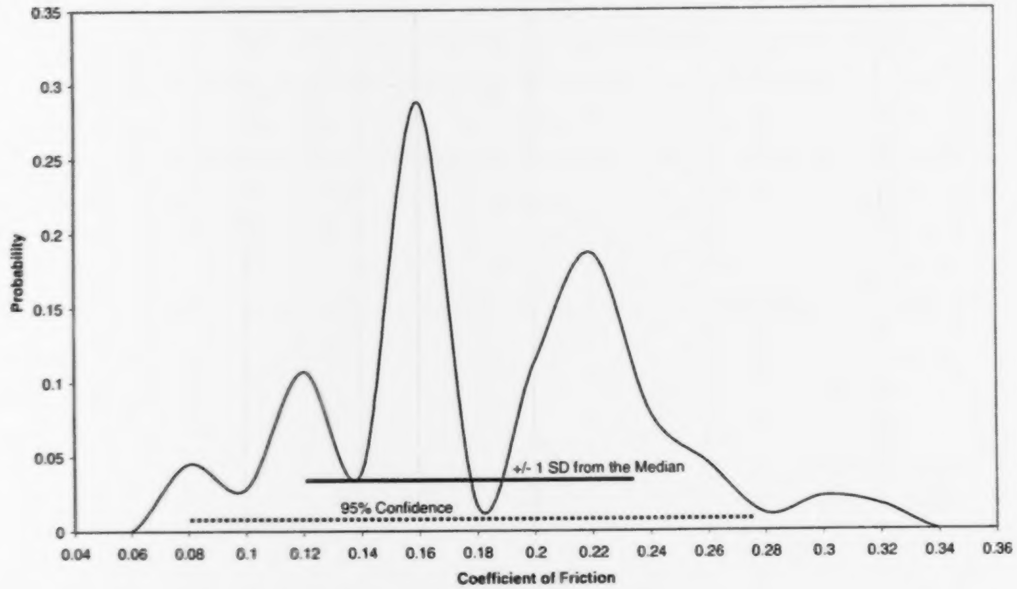
Probability Distribution for IRV-Force on Loose Snow on Pavement Between 3 and 25 mm Deep



Probability Distribution for IRV-Torque on Bare Ice and on Loose Snow on Ice <= 3 mm Deep Combined

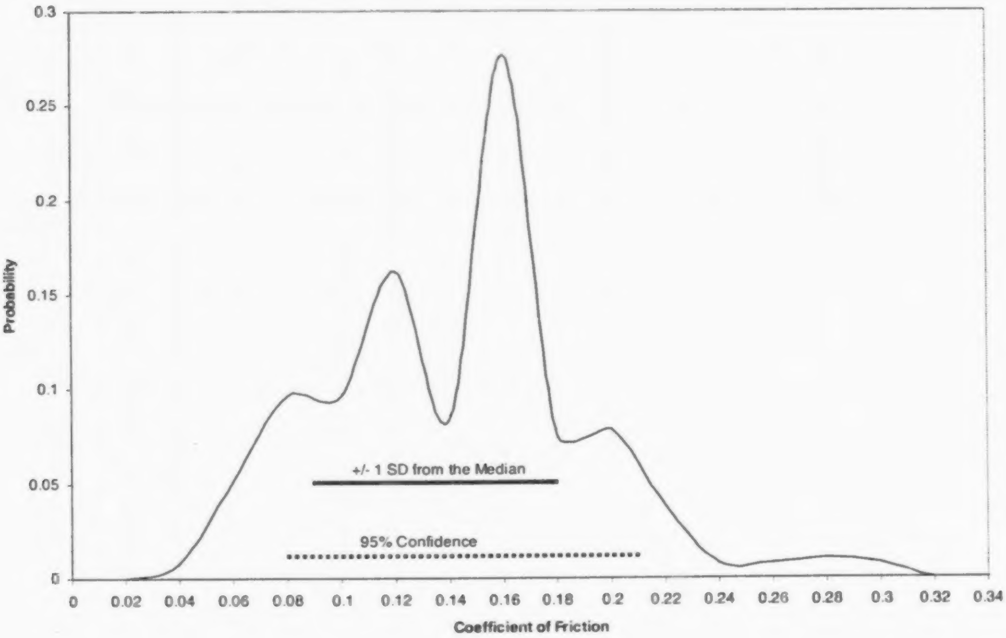


Probability Distribution for IRV-Force on Bare Ice and on Loose Snow on Ice <= 3 mm Deep Combined

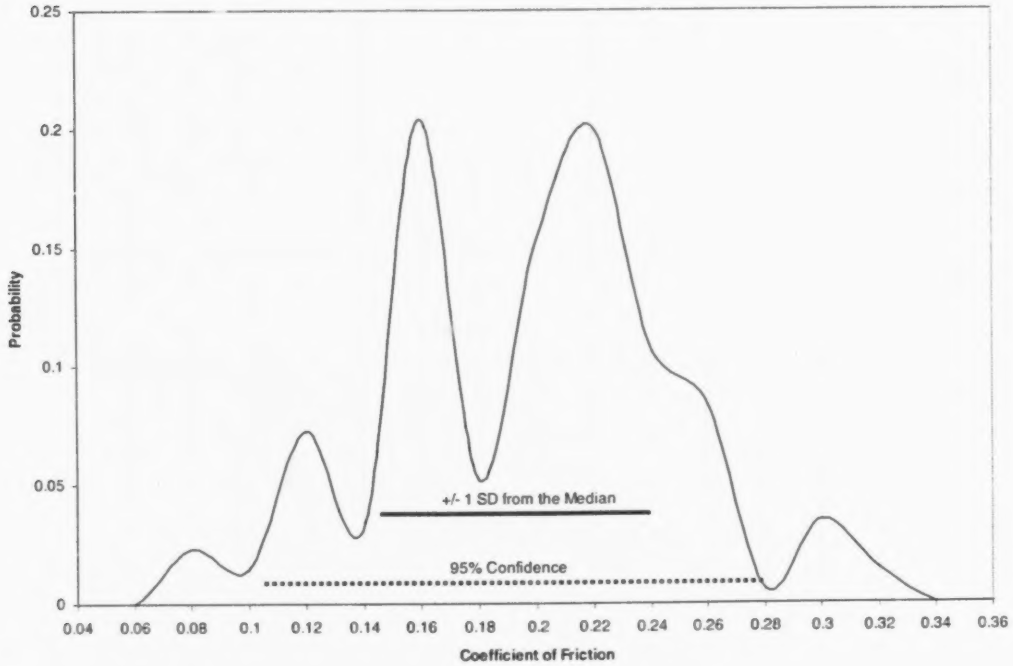


APPENDIX B.4

HISTOGRAMS FOR IRV AND IMAG COMBINED

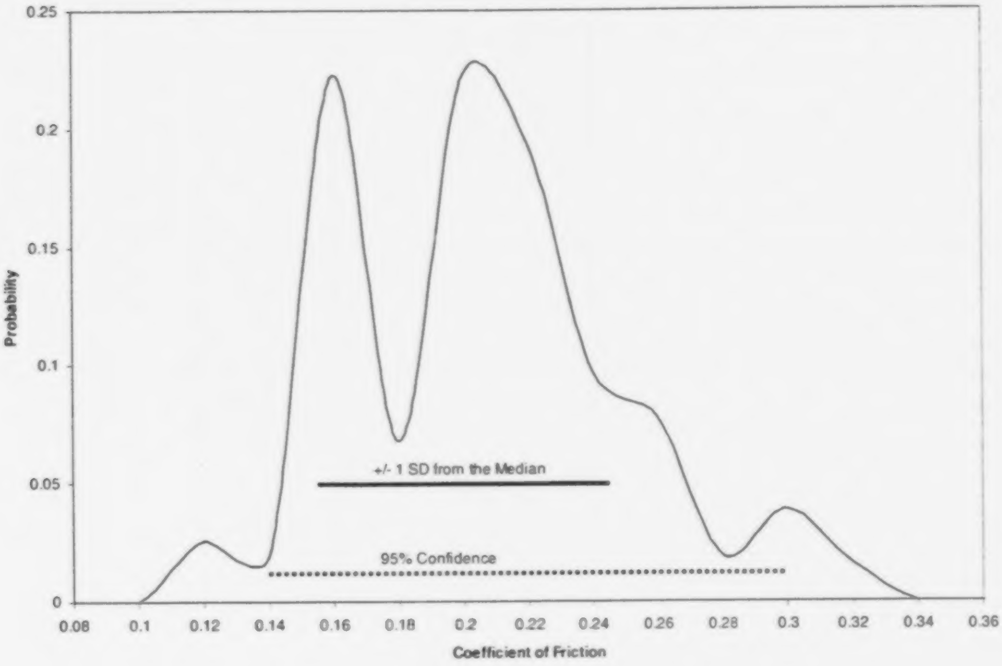


Probability Distribution for IRV and IMAG Torque Combined on Bare Ice

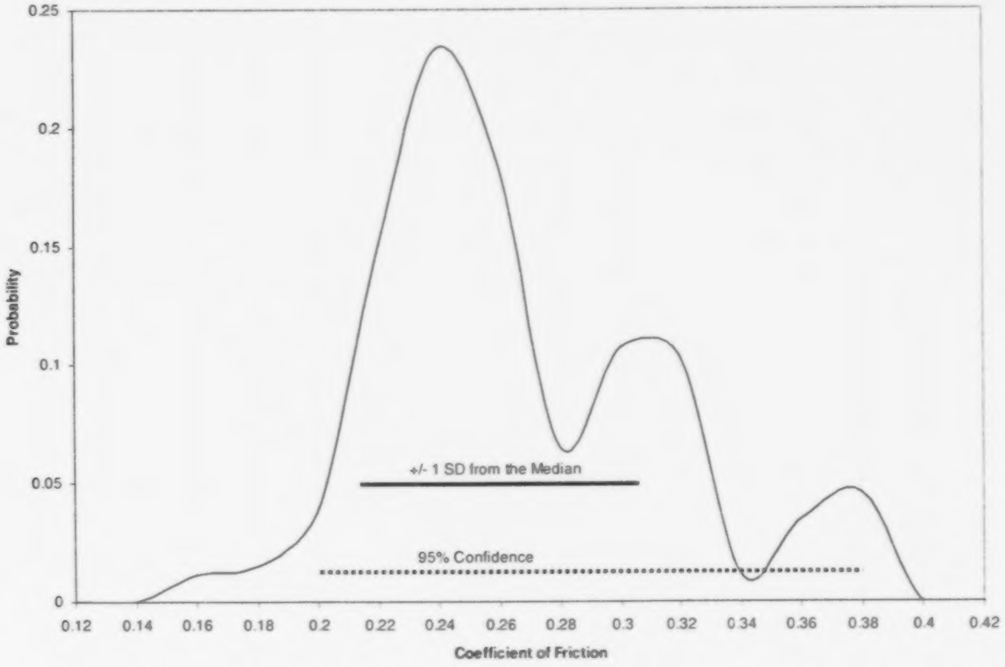


Probability Distribution for IRV and IMAG Force Combined on Bare Ice

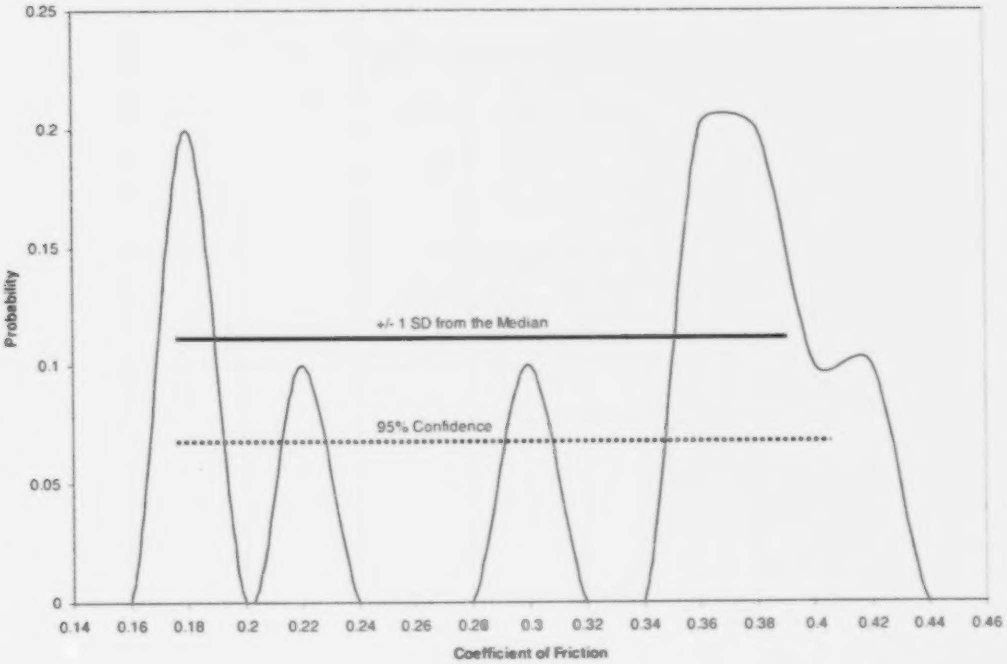
Probability Distribution for IRV and IMAG Torque Combined on Bare Packed Snow



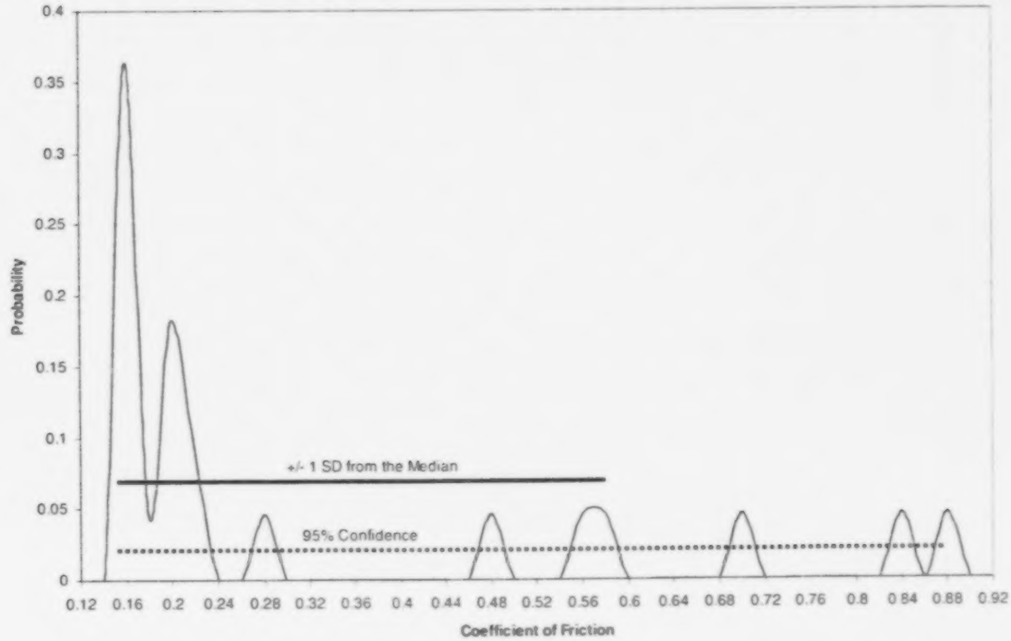
Probability Distribution for IRV and IMAG Combined on Bare Packed Snow



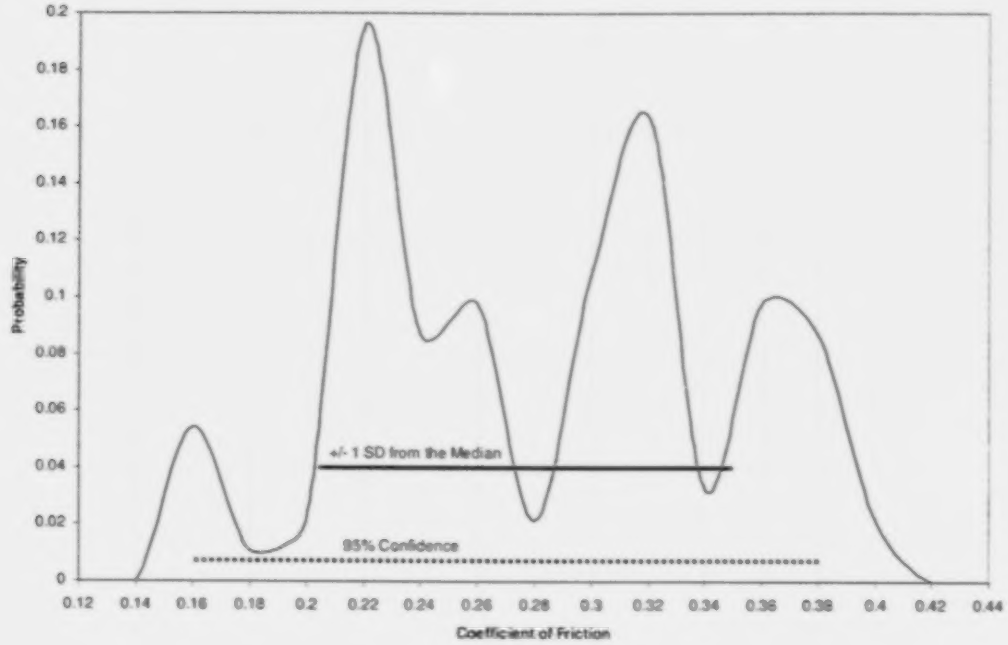
Probability Distribution for IRV and IMAG Torque Combined on Sanded Ice



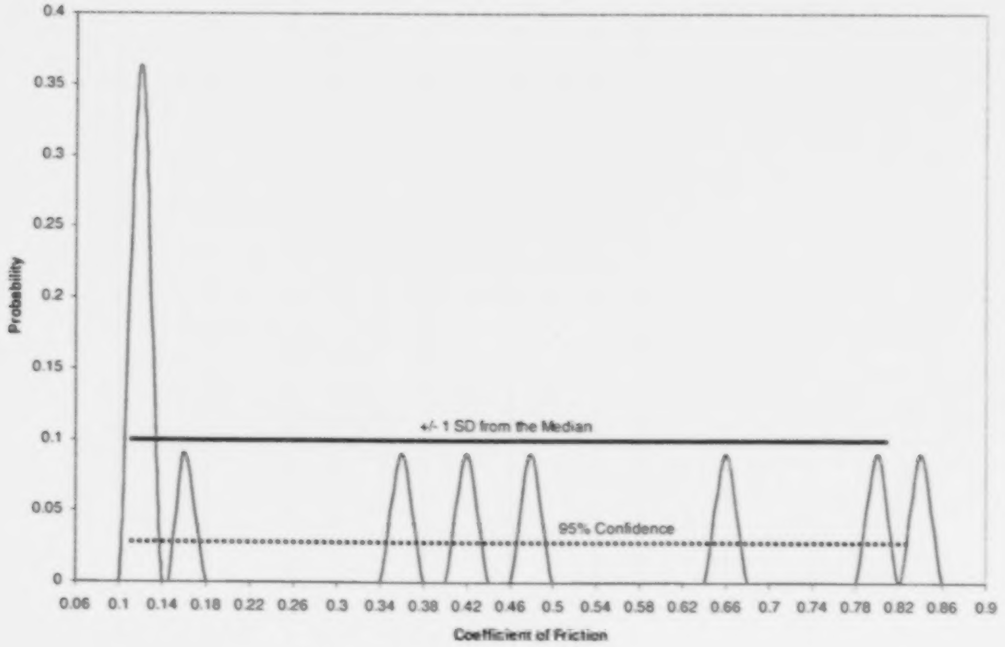
Probability Distribution for IRV and IMAG Force Combined on Loose Snow on Pavement
Less Than 3 mm Deep



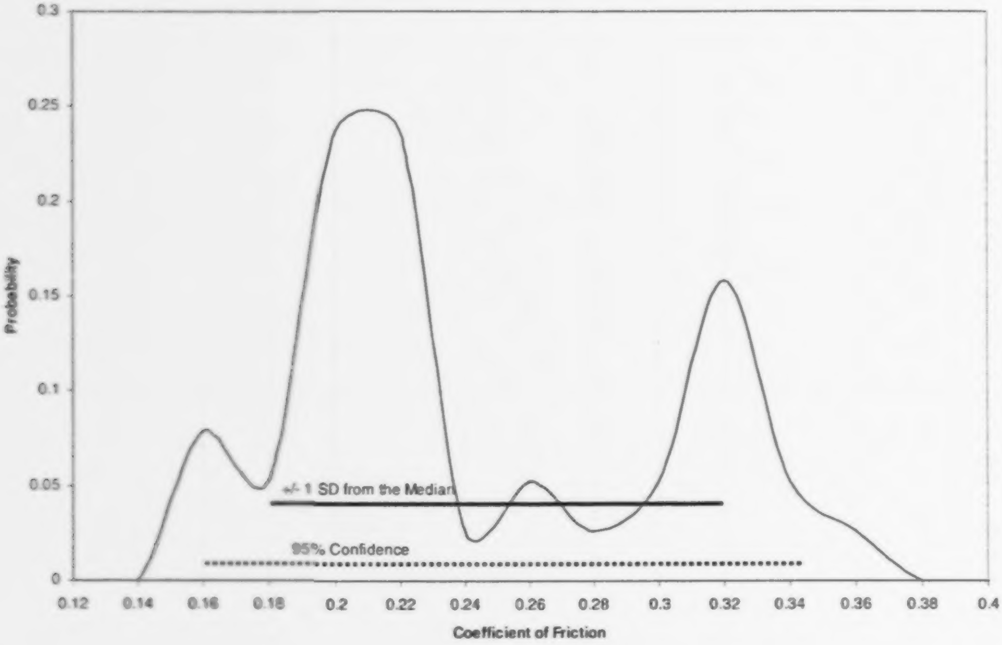
Probability Distribution for IRV and IMAG Force Combined on Loose Snow on Pavement
Between 3 and 25 mm Deep



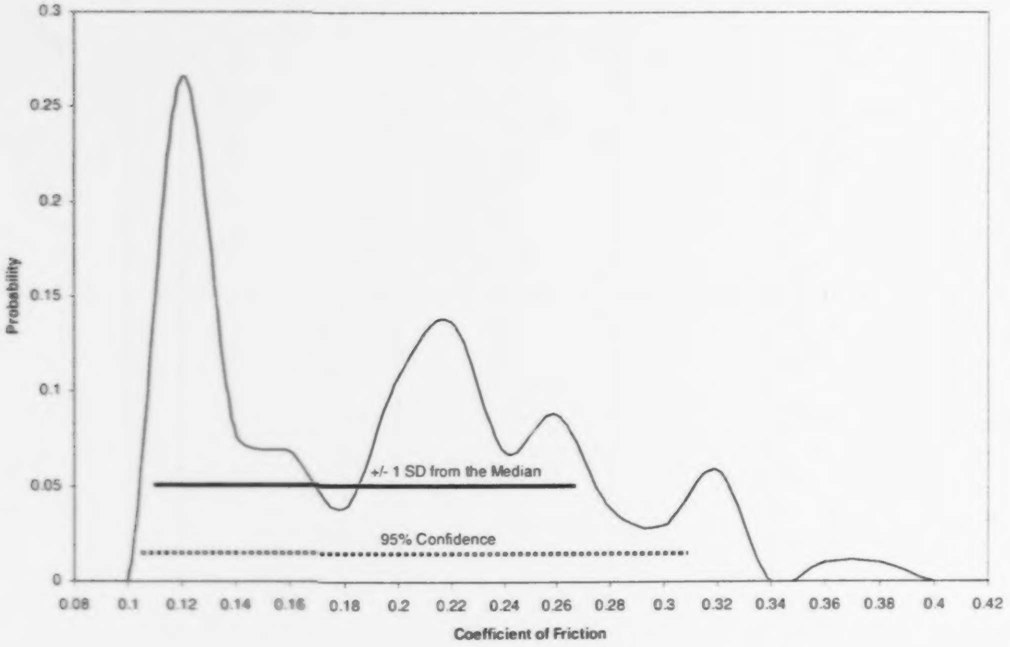
Probability Distribution for IRV and IMAG Torque Combined on Loose Snow on Pavement
Less Than 3 mm Deep

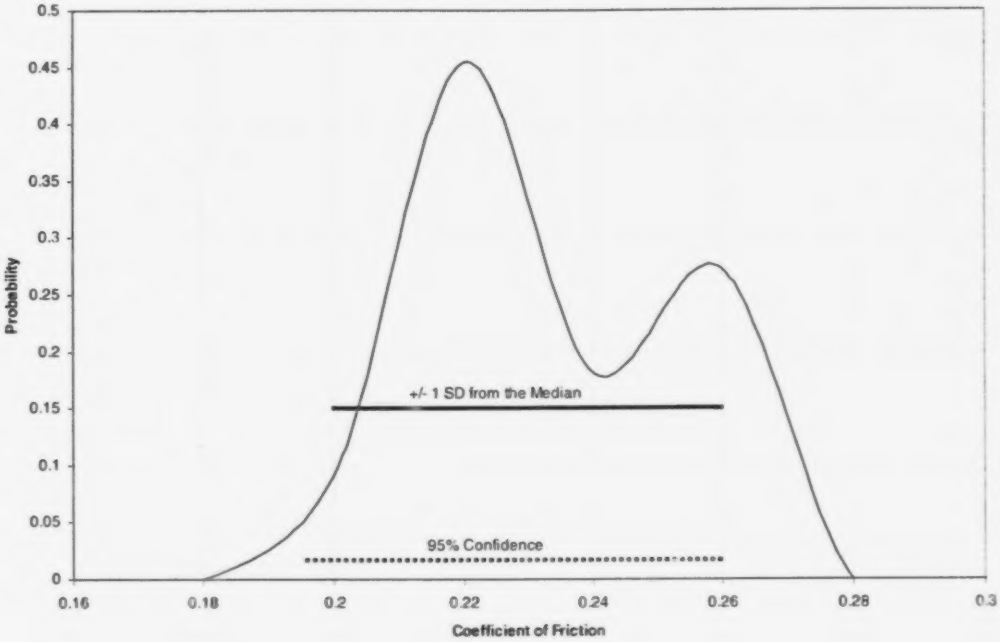


Probability Distribution for IRV and IMAG Force Combined on Loose Snow on Ice Between 3 and 25 mm Deep

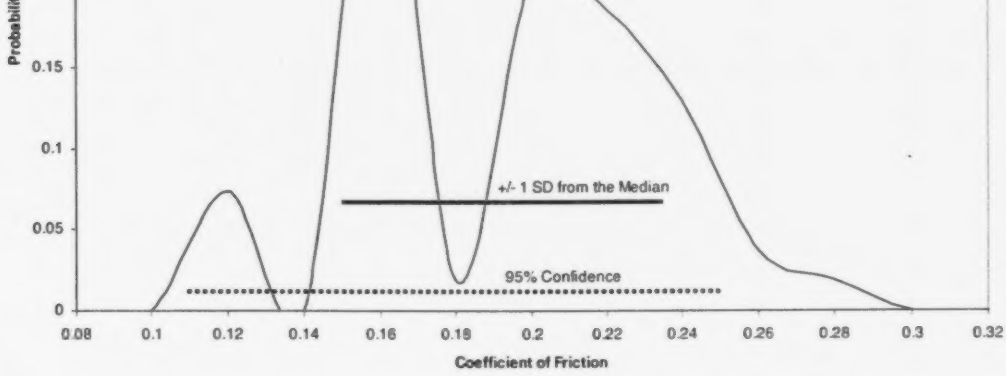


Probability Distribution for IRV and IMAG Torque Combined on Loose Snow on Pavement Between 3 and 25 mm Deep

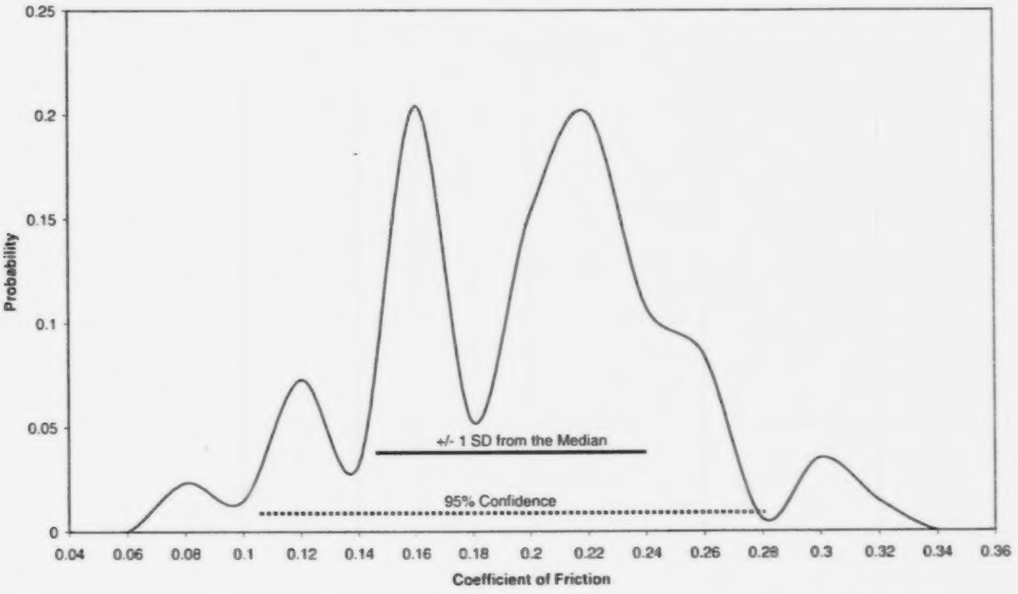




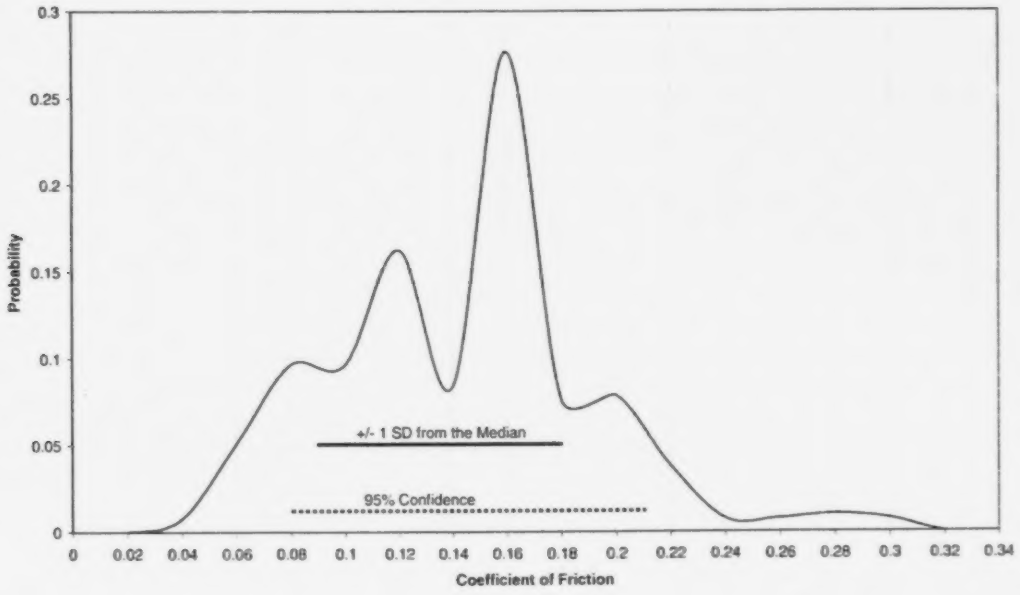
Probability Distribution for IRV and IMAG Force Combined on Loose Snow on Packed Snow Between 3 and 25 mm Deep



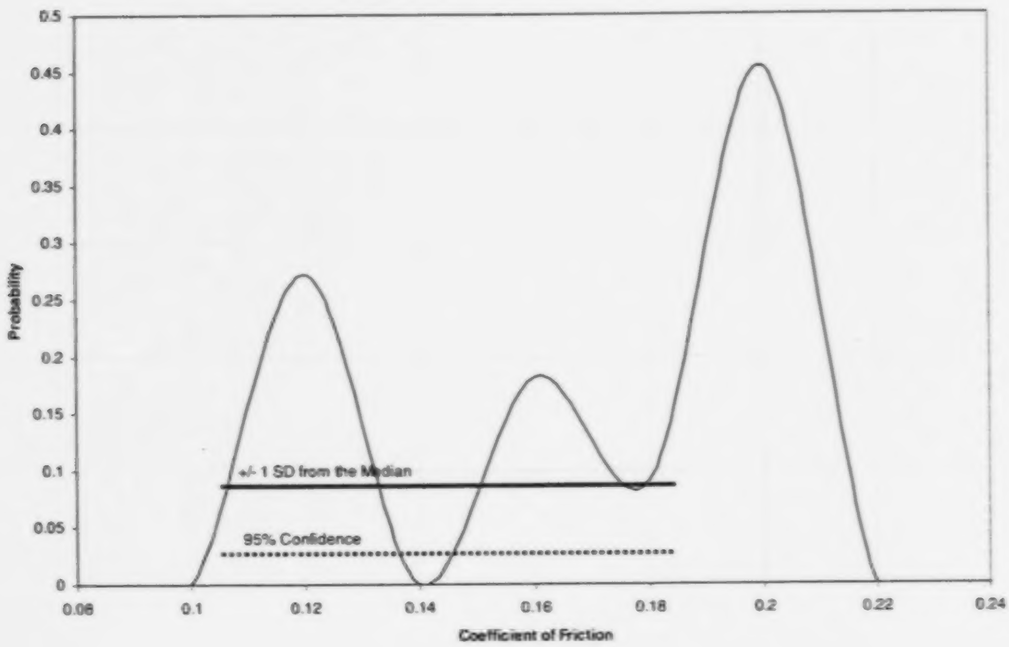
Probability Distribution for IRV and IMAG Torque Combined on Loose Snow on Ice Between 3 and 25 mm Deep



Probability Distribution for IRV and IMAG Force Combined on Bare Ice and on Loose Snow on Ice <= 3 mm Deep



Probability Distribution for IRV and IMAG Torque Combined on Bare Ice and on Loose Snow on Ice <= 3 mm Deep


Probability Distribution for IRV and IMAG Torque Combined on Loose Snow on Packed Snow Between 3 and 25 mm Deep

APPENDIX C

COMMUNICATIONS

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	Work Plan, Meeting Minutes, and Technical Submission (January 14, 2004)
Appendix C.2	Meeting Notes and Minutes (January 28, 2004)
Appendix C.3	CRFI Updates for the AIP: Further Analysis of Outliers & Assessment of "Reality Limits" (April 20, 2004)
Appendix C.4	CRFI Updates for the AIP: Range of Values to be Included (June 22, 2004)
Appendix C.5	CRFI Updates for the AIP: Comparison of SFT Data (March 31, 2004)

APPENDIX C.1

OUTLIERS AND RESULTS FROM THE 2002 AND 2003 DECELEROMETER TEST PROGRAMS

WORK PLAN, MEETING MINUTES, AND TECHNICAL SUBMISSION (JANUARY 14, 2004)

Jan. 14, 2004
BMT FTL File 5699

To: Angelo Boccanfuso, Transportation Development Centre
Dominic Morra, Aerodrome Safety

From: George Comfort, BMT Fleet Technology Ltd.
cc: Al Mazur

Follow-on from the December Meeting:
Outliers and Results from the 2002 and 2003 Decelerometer Test Programs

To follow up our December meeting, we have:

(a) investigated various methods for treating minimum and maximum CRFIs with respect to the various surfaces of interest (for inclusion in the AIP).
(b) analyzed the CRFI data from the 2002 and 2003 decelerometer test programs.

This memo was sent to mainly present information to assist decision-making for the remainder of the study.

1.0 Treatment of Outliers

1.1 Objectives and General Discussion

Previous analyses using the JWRFMP database [3] have shown that the CRFIs measured for a given surface may vary greatly. For example, CRFIs up to about 0.7 were measured for bare ice (Figure 1.1).

It was felt that this range of CRFIs may not be representative for a number of reasons such as:

(a) surfaces were non-uniform in some cases for the JWRFMP which made it difficult to describe or classify them accurately. Also, the surfaces changed during testing due to the passage of the friction-measuring vehicles. For example, the high CRFIs seen for bare ice (of about 0.7 – Figure 1.1) might have been produced if the surface had consisted of a thin, patchy ice layer overlaying pavement; and the particular device (the IMAG in this case – Figure 1.1) had been one of the last ones to traverse the surface.

(b) because the JWRFMP was a research program, it included some tests on surfaces that were not operational ones.

It was therefore decided (during the meeting) that the CRFI information to be provided in the AIP should not span the full range of the measured data.

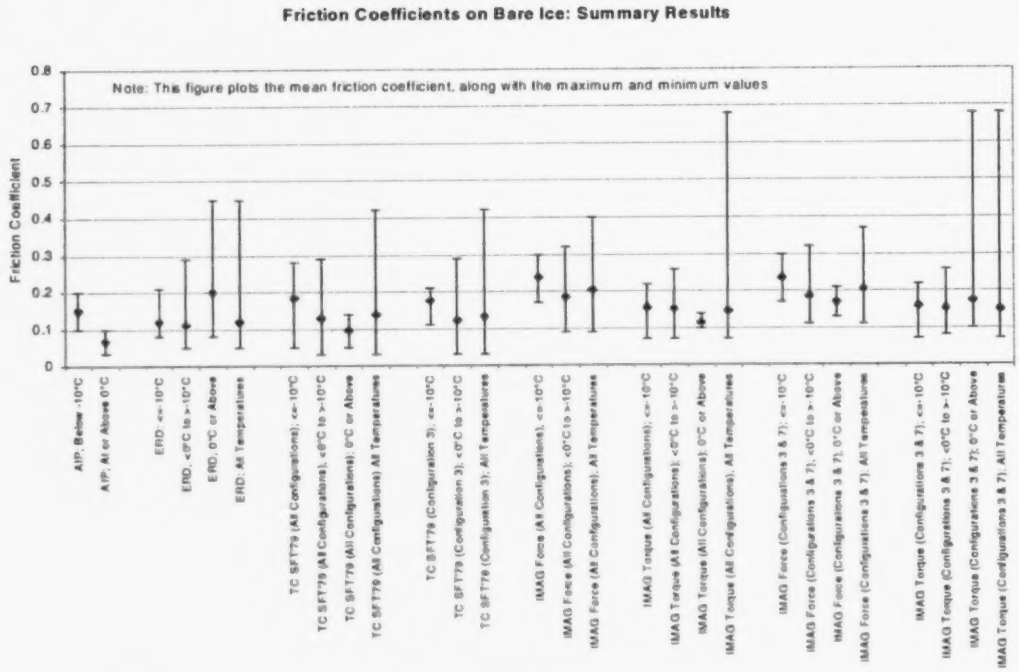


Figure 1.1: CRFIs Measured for Bare Ice (after [1])

Appropriate measures for limiting the CRFI range were considered. They included:

(a) implementing "reality" checks in accordance with pre-set CRFI limits. For example, it is well-known that the maximum CRFI of 0.68 (in Figure 1.1) is too high for ice, and that the "0.68" is probably a pavement surface. While this approach makes sense physically, it suffers from the drawback that it is subjective.

(b) cutting the CRFI range shown in the AIP to some fraction of the whole distribution (say the mean CRFI +/- 1, or 2 standard deviations (sd) from it). This suffers from the following disadvantages:
   a. it implicitly assumes that the high and low outliers are valid data points. This may be incorrect as described in (a) above.
   b. most of the measured CRFI distributions were not normal. Typically, the CRFI distributions would probably be best approximated as a lognormal distribution although this would vary on a case-by-case basis. Thus, a simple addition and subtraction (of say, +/- 1 or 2 sds) would produce CRFIs less than zero in many cases. This is clearly unreasonable.

Consequently, a two-step combination of the two general approaches above was tried here as follows:

(a) Step # 1 - "reality" limits: it was assumed that any surface with a winter contaminant (i.e., ice, snow, slush, etc) would have a CRFI less than 0.5. CRFI data of 0.5 or more were removed from the distribution.

(b) Step # 2 – statistical analyses based on the truncated distributions: values were determined by integrating the area under the distributions such that upper and lower bound values were determined as follows:
   a. 67% of the total area – this corresponds to +/- 1 sd from the mean for a normal distribution.
   b. 96% of the total area – this corresponds to +/- 2 sds from the mean for a normal distribution.

1.2 Sample Results: IMAG on Bare Ice

This case was selected as a simple query of the JWRFMP database [3] produced an unreasonably high peak CRFI for it (Figure 1.1). The underlying data indicate that the peak CRFI measured for this distribution (of 0.68) was greatly removed from the main body of the distribution (Figure 1.2), indicating that it is an outlier. The next highest CRFI (of 0.42) would also appear to be an outlier (Figure 1.2).

For these sample analyses, the distribution was altered such that the "0.68" was removed. The "0.42" was retained as it is less than 0.5 (which was the cutoff selected here).

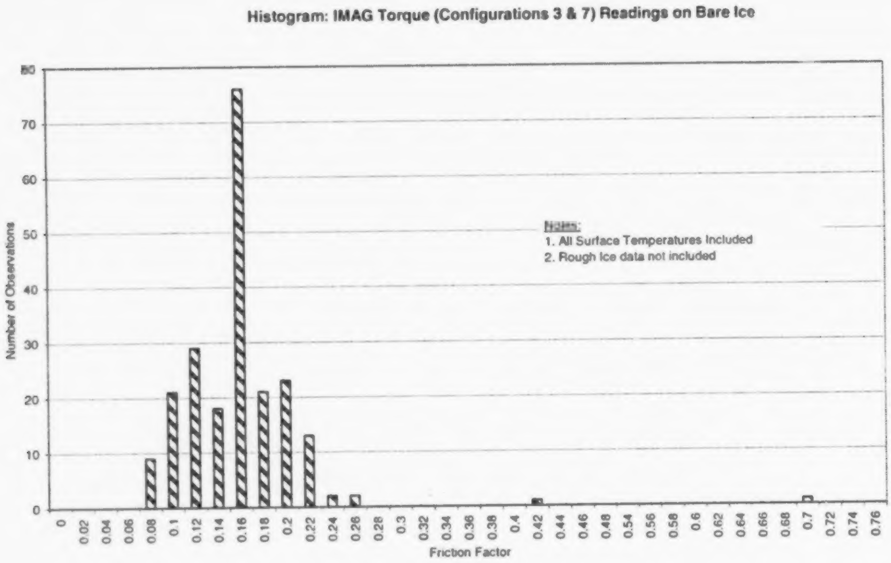


Figure 1.2: Histogram: IMAG Torque Readings on Bare Ice

The upper-range and lower-range CRFIs that would encompass 67% and 96% of the area under the revised distribution were determined to be:

(a) 67% of the area encompassed (equivalent to +/- 1 sd for a normal distribution):
   a. upper-range CRFI: 0.18

   b. lower-range CRFI: 0.10

(b) 96% of the area encompassed (equivalent to +/- 2 sd for a normal distribution):
   a. upper-range CRFI: 0.21
   b. lower-range CRFI: 0.08

1.3 Sample Results: ERD on Bare Ice

This case was selected as a simple query of the JWRFMP database [3] produced reasonable values for the CRFI range (Figure 1.1). The peak CRFI measured for this distribution was 0.45. It was well-removed from main body of the distribution (Figure 1.3). However, because it was less than 0.5, the distribution was not altered. The upper-range and lower-range CRFIs that would encompass 67% and 96% of the area under the distribution were determined to be:

(a) 67% of the area encompassed (equivalent to +/- 1 sd for a normal distribution):
   a. upper-range CRFI: 0.16
   b. lower-range CRFI: 0.09

(b) 96% of the area encompassed (equivalent to +/- 2 sd for a normal distribution):
   a. upper-range CRFI: 0.29
   b. lower-range CRFI: 0.07

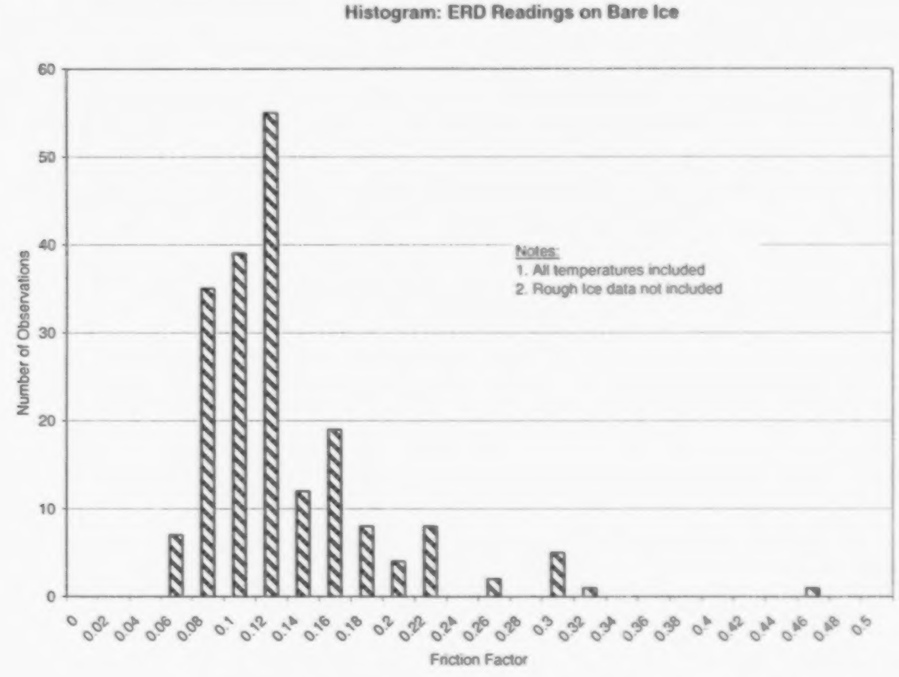


Figure 1.3: Histogram: ERD Readings on Bare Ice

2.0 CRFI data from the 2002 and 2003 Decelerometer Test Programs

2.1 Data Sources and Analysis Approach

Data from the following tests were included:

(a) 2002 data collected at North Bay airport [1] – data were included as follows:
   a. decelerometer types – all were included. However, most of the data were from ERDs.
   b. vehicles – all were included
   c. ABS on vs off – only the "ABS off" data were included.
   d. Weight Distribution – only the "as-is" data were included. The data obtained with a 50:50 weight distribution for the ½ ton pickup truck were not included.
   e. Surfaces – all were included. They were subdivided into categories.
   f. Temperatures - all were included. They were subdivided into categories.
   g. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(b) 2003 data collected at North Bay airport to investigate the effect of ABS on vs off [2] – data were included as follows:
   a. decelerometer types – all were included. However, most of the data were from ERDs.
   b. vehicles – all were included
   c. ABS on vs off – only the "ABS off" data were included.
   d. Surfaces – all were included. They were subdivided into categories.
   e. Temperatures - all were included. They were subdivided into categories.
   f. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(c) 2003 data collected during CRFI Quality Assurance tests at five airports [2] – data were included as follows:
   a. decelerometer types – all of the data were from ERDs. Unreliable data (e.g., from TC's ERD Mk III) were not included.
   b. vehicles & operators – all data were included.
   c. airports, circuits & runs – all data were included.
   d. surfaces – all were included. They were subdivided into categories.
   e. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

2.2 CRFIs on Bare Ice

CRFIs for bare ice are listed in Table 2.1. For reference, this table also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of available data, especially for the "<=-10°C" temperature case. Except for the ">=0°C" temperature case, the data quantity is considered to be sufficient to allow trends and conclusions to be established reliably.
(b) CRFI magnitudes – the 2002 & 2003 decelerometer data correlated reasonably well with the JWRFMP data.

(c) Effect of Temperature – the CRFIs were not strongly affected by temperature. The ">=0°C" temperature data may represent an exception to this statement. However, the data quantity for this case is quite small (i.e., only 6 observations).

Table 2.1: CRFIs Measured by Decelerometers on Bare Ice

Data Source		Surface Temperature Range			
		<= -10°C	<0°C to >-10°C	>=0°C	All Temps
JWRFMP [3][1]	Mean	0.12	0.11	0.20	0.12
	St Dev	0.0394	0.0463	0.1322	0.0544
	Max	0.21	0.29	0.45	0.45
	Min	0.08	0.05	0.08	0.05
	# of Obs	10	146	6	196[2]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.15	0.13	no data	0.14
	St Dev	0.0867	0.0384	no data	0.0665
	Max	0.47	0.24	no data	0.47
	Min	0.09	0.06	no data	0.06
	# of Obs	41	43	0	84

Notes:

1. These results do not include "rough ice" which is a separate surface category in the JWRFMP database.
2. The # of observations for all temperatures is more than the sum of the three temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.

2.2 CRFIs on Bare Packed Snow

CRFIs for bare ice are listed in Table 2.2. For reference, this table also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of data available for the "<=-15°C" temperature case. The data quantity for the ">-15°C" temperature case was not increased substantially by including the 2002 & 2003 test data. The data quantity is considered to be sufficient to allow trends and conclusions to be established reliably for all temperature cases.

(b) CRFI magnitudes – the 2002 & 2003 decelerometer data correlated reasonably well with the JWRFMP data.

(c) Effect of Temperature – the CRFIs were not strongly affected by temperature.

Table 2.2: CRFIs Measured by Decelerometers on Bare Packed Snow

Data	Surface Temperature Range			
Source		<= -15°C	>-15°C	All Temps
JWRFMP [3]	Mean	0.29	0.18	0.20
	St Dev	0.005	0.0635	0.0663
	Max	0.29	0.63	0.63
	Min	0.28	0.09	0.09
	# of Obs	4	138	186[1]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.22	0.25	0.23
	St Dev	0.0719	0.0377	0.0655
	Max	0.33	0.29	0.33
	Min	0.09	0.17	0.09
	# of Obs	24	9	33

Notes:

1. The # of observations for all temperatures is more than the sum of the two temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.

2.4 CRFIs on Sanded Ice and Sanded Packed Snow

CRFIs for sanded ice and sanded packed snow are listed in Tables 2.3 and 2.4, respectively. For reference, Table 2.3 also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of data available for sanded packed snow (as there are no data in the JWRFMP database for this case); the available data quantity is now considered to be sufficient to allow reliable analyses. With respect to sanded ice, although the 2002 & 2003 decelerometer test data have significantly increased the data quantity, the number of observations for sanded ice is still small which will limit the strength of the conclusions that can be drawn for this case.

(b) CRFI magnitudes for sanded ice – sanding increased the CRFI by about 0.1. Compare Tables 2.1 and 2.3.

(c) CRFI magnitudes for sanded packed snow – sanding did not increase the CRFI substantially. Compare Tables 2.2 and 2.4.

(d) Effect of Temperature for sanded ice – insufficient data are available to make firm statements.

(e) Effect of Temperature for sanded packed snow – higher CRFIs were measured for the warmer temperature case (i.e., >-15°C).

Table 2.3: CRFIs Measured by Decelerometers on Sanded Ice

Data Source		Surface Temperature Range			
		<= -10°C	<0°C to >-10°C	>=0°C	All Temps
JWRFMP [3][1]	Mean	0.30	0.26	0.23	0.24
	St Dev	no data[3]	0.0929	no data[3]	0.0513
	Max	no data[3]	0.34	no data[3]	0.34
	Min	no data[3]	0.16	no data[3]	0.16
	# of Obs	1	3	1	12[2]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.23	0.31	no data	0.25
	St Dev	0.0183	0.0629	no data	0.0487
	Max	0.25	0.38	no data	0.38
	Min	0.20	0.25	no data	0.20
	# of Obs	12	4	0	16

Notes:

1. These results do not include "rough ice" which is a separate surface category in the JWRFMP database.
2. The # of observations for all temperatures is more than the sum of the three temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.
3. Only one observation.

Table 2.4: CRFIs Measured by Decelerometers on Sanded Packed Snow

Data Source	Surface Temperature Range			
		<= -15°C	>-15°C	All Temps
JWRFMP [3][1]	Mean	no data	no data	no data
	St Dev	no data	no data	no data
	Max	no data	no data	no data
	Min	no data	no data	no data
	# of Obs	0	0	0
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.26	0.37	0.35
	St Dev	0.0584	0.0845	0.0811
	Max	0.31	0.53	0.53
	Min	0.14	0.25	0.14
	# of Obs	12	61	73

Notes:

1. There are no data in the JWRFMP database for sanded packed snow.

2.5 CRFIs on Surfaces With Loose Snow on Top – Effect of Snow Depth

2.5.1 CRFIs for Loose Snow on Pavement

The 2002 & 2003 decelerometer tests [1], [2] provided 54 data points. This is a significant addition to the 121 observations obtained from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.1. Snow depths less than 3 mm (1/8") caused a substantial drop in CRFI. The CRFI was not affected by a snow depth variation from 3 to 6 mm (1/8 to ¼"). This trend shows that only a small amount of snow on the pavement will degrade its CRFI such that it is effectively "snow" rather than bare pavement.

For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.2. Although the JWRFMP data span a much wider range of snow depths, they also support the above observation. The 2002 & 2003 decelerometer data assist in defining the relationship for small snow depths.

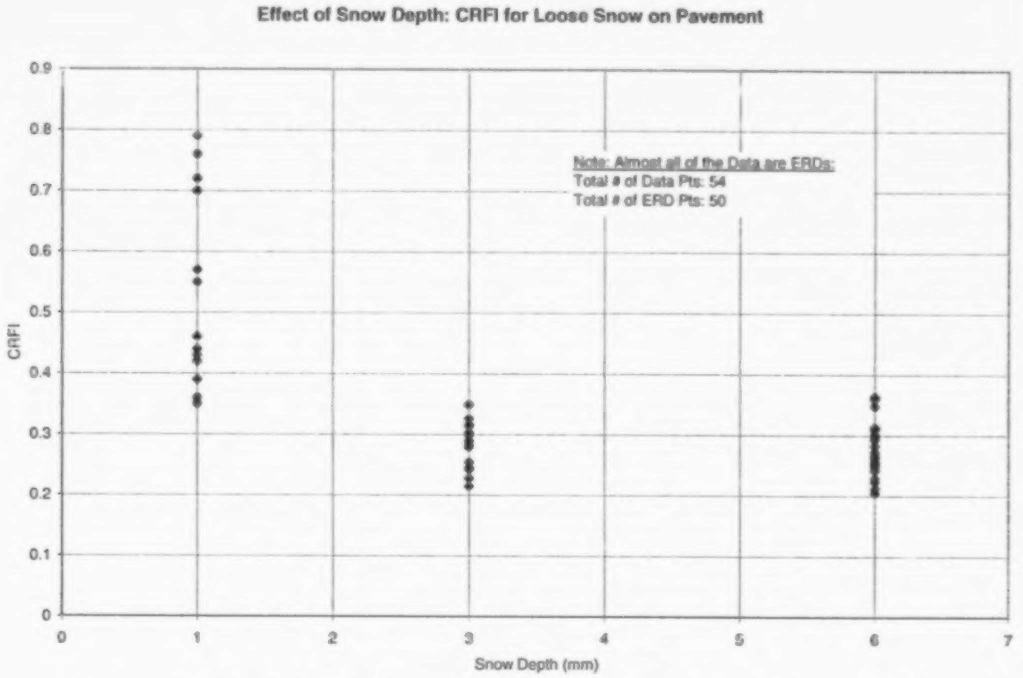


Figure 2.1: Effect of Snow Depth: 2002 and 2003 Decelerometer Data for Loose Snow on Pavement

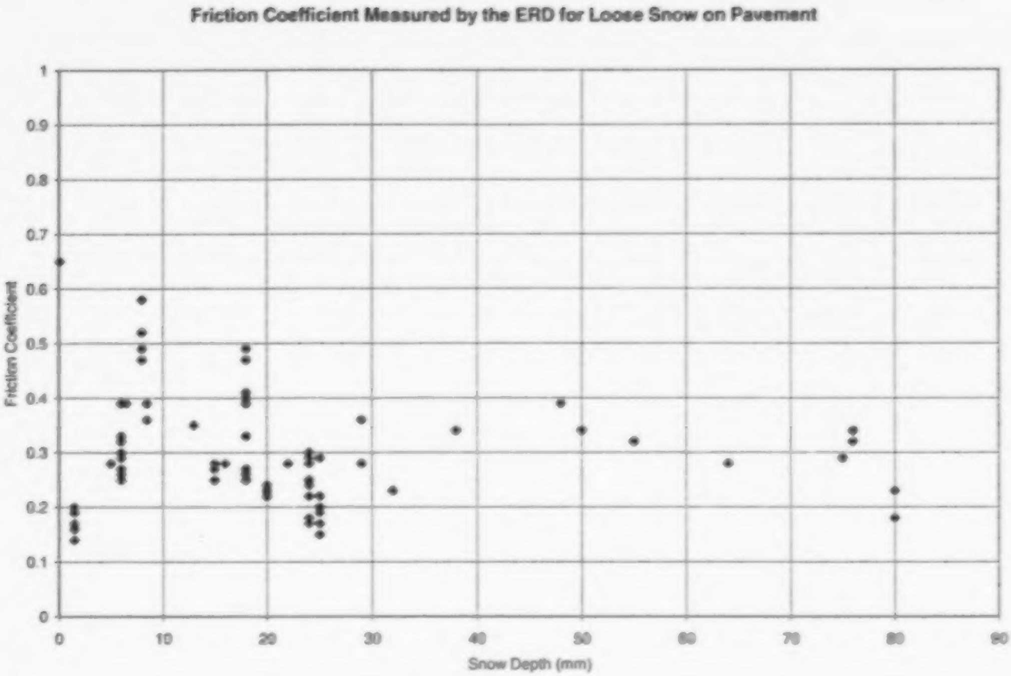


Figure 2.2: Effect of Snow Depth: JWRFMP Data for Loose Snow on Pavement [3]

2.5.2 CRFIs for Loose Snow on Packed Snow

The 2002 & 2003 decelerometer tests [1], [2] provided 54 data points. This is a significant addition to the 27 observations obtained from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.3. For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.4. Both data sets indicate that CRFIs for snow-covered packed snow are substantially affected by snow depth, for depths up to about 40 mm.

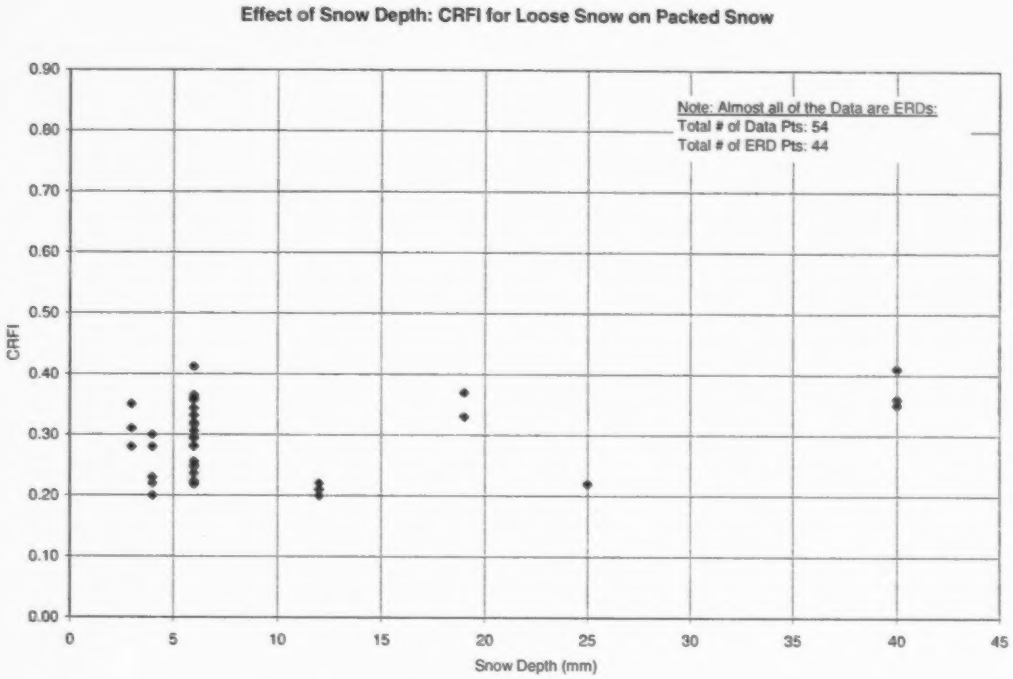


Figure 2.3: Snow Depth Effect: 2002 & 2003 Decelerometer Data for Snow on Packed Snow

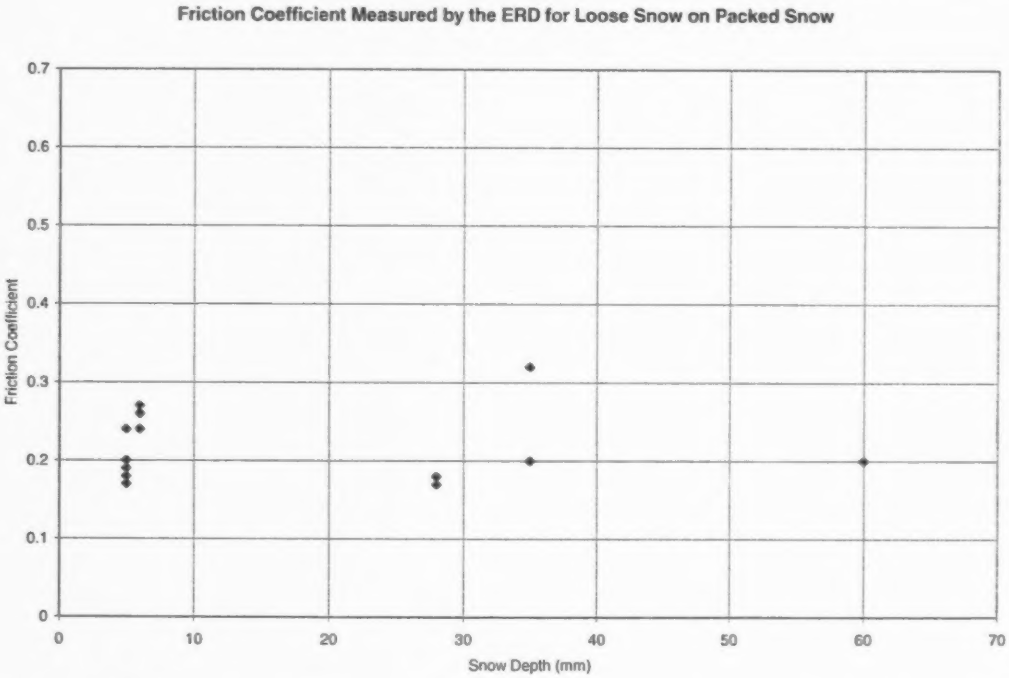


Figure 2.4: Snow Depth Effect: JWRFMP Data for Loose Snow on Packed Snow [3]

2.5.3 CRFIs for Loose Snow on Ice

The 2002 & 2003 decelerometer tests [1] [2] provided some more data points (i.e., 15) to add to the 95 observations available from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.5. For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.6. The JWRFMP data indicate that the CRFIs measured by decelerometers increase steadily with snow depth, although the relationship is scattered. The 2002 & 2003 decelerometer test data would fall within the general data band from the JWRFMP.

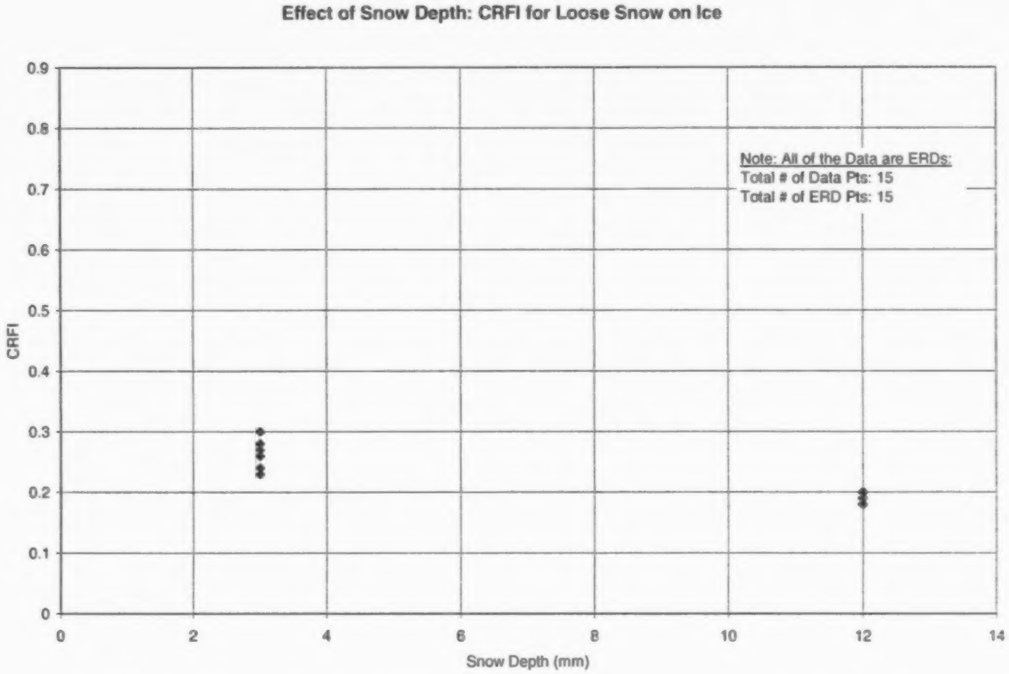


Figure 2.5: Effect of Snow Depth: 2002 & 2003 Decelerometer Data for Loose Snow on Ice

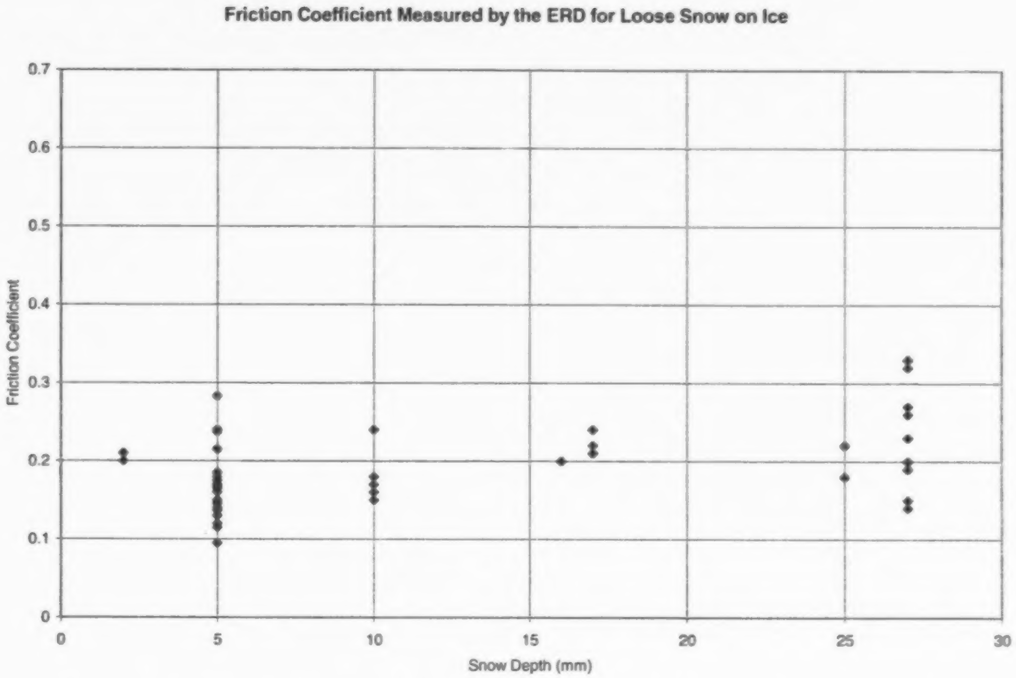


Figure 2.6: Effect of Snow Depth: JWRFMP Data for Loose Snow on Ice [3]

3.0 Concluding Remarks

This memo was sent to mainly present information to assist decision-making for the remainder of the study. The following comments can be made:

(a) Outliers and establishing CRFI ranges - the combined approach (of using both reality checks and some fraction of the distribution) produces reasonable results. Both the reality limits and the fraction need to be selected with care as they both affect the results. The key question that needs to be addressed is:

- What degree of variability should the guidelines in the AIP reflect?

We seek your input regarding this.

(b) 2002 & 2003 Decelerometer Test Data – these data augment the previous analyses considerably. We suggest that all subsequent analyses should be done using the combined data set (i.e., the JWRFMP database plus the 2002 & 2003 decelerometer test program results).

4.0 References

[1] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP13980E.

[2] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP# to come.

[3] Comfort, G., 2003, Effect of Surface Conditions on the Friction Coefficients Measured on Winter Surfaces, Transport Canada report, TP# to come.

CRFI/AIP Information Update Project (Contract # T8200-033527/001/MTB)

Work Plan, Meeting Minutes and Technical Submission

Date: Jan. 14 2004
By: G. Comfort, BMT Fleet Technology Ltd.
To: Transport Canada

Introduction and Purpose

A kickoff meeting was held with Transport Canada representatives during December 2003. This is intended as a combined Work Plan, Meeting Minutes and Technical Submission. It is intended to summarize the key points arising from the meeting. A number of technical issues arose during the meeting that needed investigation before an appropriate decision could be made. The attached Technical Submission (Annex A) was prepared to address this need.

We hope that this meets your needs. We look forward to your input, particularly regarding the required format of the information (item (g) below, and Annex A), as well as for any other issues.

Objectives

The objectives of this project are:

a) to provide information on the variability of CRFI due to winter contaminated surface conditions.
b) to provide a CRFI/surface condition equivalency chart for consideration for inclusion in the AIP
c) to use data from the JWRFMP database and from other relevant sources as the technical basis in determining a) and b).

Work Plan and Key Points Arising During the December 2003 Meeting

The following work plan takes into account FTL's proposal that was put forward at the meeting, and it outlines the major activities and approach that will be followed.

(a) The work should satisfy two objectives as follows. The report should separate out the information provided to meet each objective.
  a. provide CRFI information required for updating the AIP – this information is specific as the CRFIs should be based on decelerometer data, and the surfaces for which they are considered to be reliable.
  b. provide a more general understanding of the effect of surface conditions on CRFIs

(b) Friction-measuring devices: Only data from field tests using decelerometers, the IMAG (in the force and torque modes) and Transport Canada's 1979 SFT will be used in the project.

(c) Data Sources: The following data sources will be used:
  a. the JWRFMP database, and previous analyses using these data [1]
  b. tests done in 2002 with decelerometers at North Bay airport [2]
  c. tests done in 2003 with decelerometers at North Bay and other airports [3]

  Note: the utility of the 2002 & 2003 decelerometer data has been investigated. These data generally support and augment the data from the JWRFMP database (Annex A).

(d) Surfaces: the available friction data for the devices will be grouped according to surface conditions as follows.

  a. Ice
  b. Wet ice
  c. Sanded Ice
  d. Compact Snow
  e. Sanded Compact Snow
  f. Loose snow on ice (not exceeding 2.5 cm)
  g. Loose snow on compact snow (less than 2.5 cm)
  h. Loose snow on pavement (not exceeding 2.5 cm)

(e) Temperatures: the friction data are to be examined. If temperature is found to be a significant factor, then the CRFI information should be subdivided by temperature as appropriate. For now, the temperature ranges used previously [1] are acceptable.

(f) Other Details regarding the Data Sources and Analysis:

  a. tests done on "Aged" snow are not to be included in the data set used for analysis
  b. the data set to evaluate the effect of snow depth is to be augmented. For records where snow depth data are not available, snow depths are to be established based on the snow category (e.g., loose snow, drifting snow, etc). This is to be done in consultation with Alice Krol.

(g) Information Format: A statistical analysis for each group will be carried out. Charts, tables, graphs will be established as required. The tables will show information such as mean, standard deviation, maximum, minimum, and the number of observations.

There was considerable discussion regarding the format of the data as the values in the JWRFMP database span a range that is considered to be unreasonably wide for operational surfaces. This full range should not be put in the AIP. FTL was asked to investigate some options. A combination of reality checks and including a specified fraction (e.g., based on 1 or 2 standard deviations) will produce reasonable results (Annex A).

Input is now required from the Client regarding this (Annex A).

(h) Information to be reviewed: Transport Canada will provide current recommendations for information in the AIP pertaining to CRFIs as well as a list of surfaces for which decelerometers are considered to be reliable. This will be reviewed by FTL along with other information that may be relevant.

(i) Commentary regarding reasons for CRFI variability: Brief technical comments in support of the chart would be useful provided that they are specific and can be supported. FTL will investigate and this issue will be re-visited.

(j) Reporting: A draft report will be prepared and submitted for review and comments prior to preparing the final report.

References

[1] Comfort, G., 2003, Effect of Surface Conditions on the Friction Coefficients Measured on Winter Surfaces, Transport Canada report, TP# to come.

[2] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP13980E.

[3] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP# to come.

ANNEX A

TECHNICAL SUBMISSION

Jan. 14, 2004
BMT FTL File 5699

To: Angelo Boccanfuso, Transportation Development Centre, Transport Canada
Dominic Morra, Aerodrome Safety, Transport Canada

From: George Comfort, BMT Fleet Technology Ltd.
cc: Al Mazur

Follow-on from the December Meeting:
Outliers and Results from the 2002 and 2003 Decelerometer Test Programs

To follow up our December meeting, we have:

(c) investigated various methods for treating minimum and maximum CRFIs with respect to the various surfaces of interest (for inclusion in the AIP).
(d) analyzed the CRFI data from the 2002 and 2003 decelerometer test programs.

This memo was sent to mainly present information to assist decision-making for the remainder of the study.

2.0 Treatment of Outliers

1.1 Objectives and General Discussion

Previous analyses using the JWRFMP database [3] have shown that the CRFIs measured for a given surface may vary greatly. For example, CRFIs up to about 0.7 were measured for bare ice (Figure 1.1).

It was felt that this range of CRFIs may not be representative for a number of reasons such as:

(c) surfaces were non-uniform in some cases for the JWRFMP which made it difficult to describe or classify them accurately. Also, the surfaces changed during testing due to the passage of the friction-measuring vehicles. For example, the high CRFIs seen for bare ice (of about 0.7 – Figure 1.1) might have been produced if the surface had consisted of a thin, patchy ice layer overlaying pavement; and the particular device (the IMAG in this case – Figure 1.1) had been one of the last ones to traverse the surface.

(d) because the JWRFMP was a research program, it included some tests on surfaces that were not operational ones.

It was therefore decided (during the meeting) that the CRFI information to be provided in the AIP should not span the full range of the measured data.

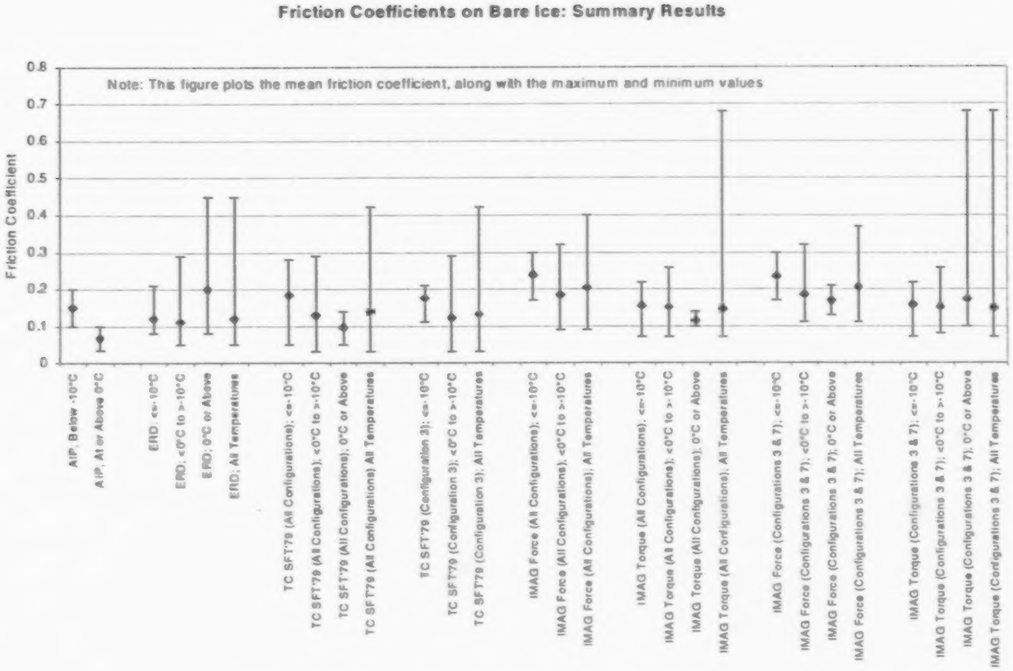


Figure 1.1 CRFIs Measured for Bare Ice (after [1])

Appropriate measures for limiting the CRFI range were considered. They included:

(c) implementing "reality" checks in accordance with pre-set CRFI limits. For example, it is well-known that the maximum CRFI of 0.68 (in Figure 1.1) is too high for ice, and that the "0.68" is probably a pavement surface. While this approach makes sense physically, it suffers from the drawback that it is subjective.

(d) cutting the CRFI range shown in the AIP to some fraction of the whole distribution (say the mean CRFI +/- 1, or 2 standard deviations (sd) from it). This suffers from the following disadvantages:
   a. it implicitly assumes that the high and low outliers are valid data points. This may be incorrect as described in (a) above.
   b. most of the measured CRFI distributions were not normal. Typically, the CRFI distributions would probably be best approximated as a lognormal distribution although this would vary on a case-by-case basis. Thus, a simple addition and subtraction (of say, +/- 1 or 2 sds) would produce CRFIs less than zero in many cases. This is clearly unreasonable.

Consequently, a two-step combination of the two general approaches above was tried here as follows:

(a) Step # 1 - "reality" limits: it was assumed that any surface with a winter contaminant (i.e., ice, snow, slush, etc) would have a CRFI less than 0.5. CRFI data of 0.5 or more were removed from the distribution.

(b) Step # 2 – statistical analyses based on the truncated distributions: values were determined by integrating the area under the distributions such that upper and lower bound values were determined as follows:

  c. 67% of the total area – this corresponds to +/- 1 sd from the mean for a normal distribution.
  d. 96% of the total area – this corresponds to +/- 2 sds from the mean for a normal distribution.

1.2 Sample Results: IMAG on Bare Ice

This case was selected as a simple query of the JWRFMP database [3] produced an unreasonably high peak CRFI for it (Figure 1.1). The underlying data indicate that the peak CRFI measured for this distribution (of 0.68) was greatly removed from the main body of the distribution (Figure 1.2), indicating that it is an outlier. The next highest CRFI (of 0.42) would also appear to be an outlier (Figure 1.2).

For these sample analyses, the distribution was altered such that the "0.68" was removed. The "0.42" was retained as it is less than 0.5 (which was the cutoff selected here).

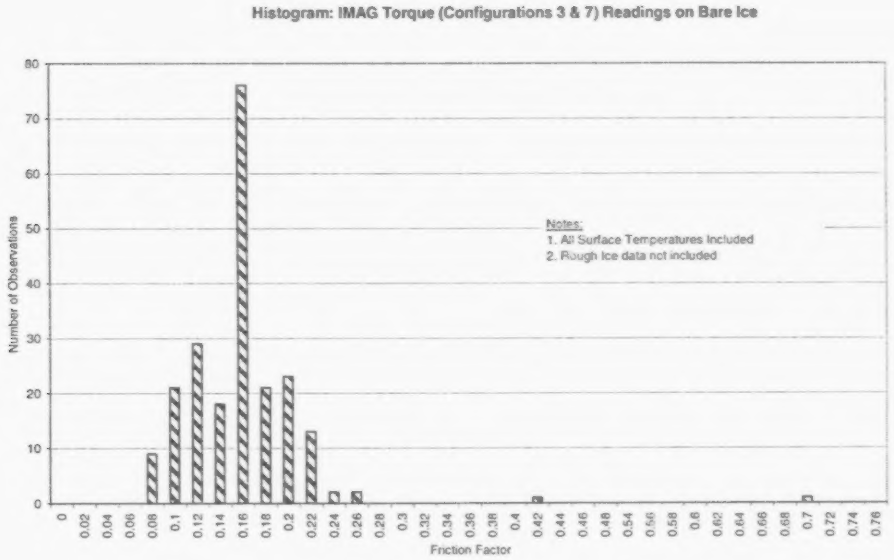


Figure 1.2 Histogram: IMAG Torque Readings on Bare Ice

The upper-range and lower-range CRFIs that would encompass 67% and 96% of the area under the revised distribution were determined to be:

(a) 67% of the area encompassed (equivalent to +/- 1 sd for a normal distribution):

  a. upper-range CRFI: 0.18
  b. lower-range CRFI: 0.10

(b) 96% of the area encompassed (equivalent to +/- 2 sd for a normal distribution):

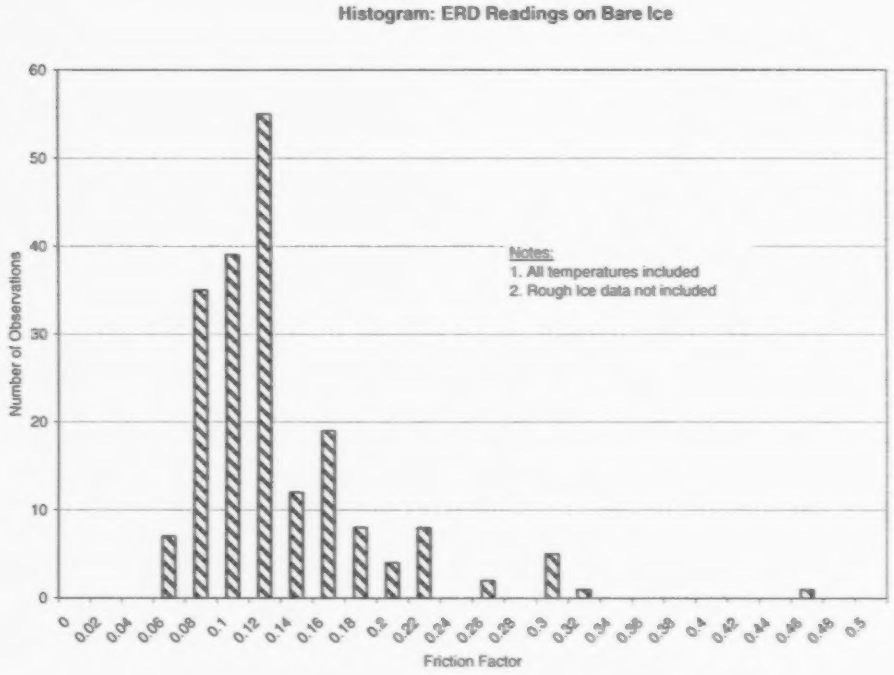
  a. upper-range CRFI: 0.21
  b. lower-range CRFI: 0.08

1.3 Sample Results: ERD on Bare Ice

This case was selected as a simple query of the JWRFMP database [3] produced reasonable values for the CRFI range (Figure 1.1). The peak CRFI measured for this distribution was 0.45. It was well-removed from main body of the distribution (Figure 1.3). However, because it was less than 0.5, the distribution was not altered. The upper-range and lower-range CRFIs that would encompass 67% and 96% of the area under the distribution were determined to be:

(a) 67% of the area encompassed (equivalent to +/- 1 sd for a normal distribution):
  a. upper-range CRFI: 0.16
  b. lower-range CRFI: 0.09

(b) 96% of the area encompassed (equivalent to +/- 2 sd for a normal distribution):
  a. upper-range CRFI: 0.29
  b. lower-range CRFI: 0.07



Notes:
1. All temperatures included
2. Rough ice data not included

Figure 1.3 Histogram: ERD Readings on Bare Ice

2.0 CRFI data from the 2002 and 2003 Decelerometer Test Programs

2.1 Data Sources and Analysis Approach

Data from the following tests were included:

(a) 2002 data collected at North Bay airport [1] – data were included as follows:

  a. decelerometer types – all were included. However, most of the data were from ERDs.
  b. vehicles – all were included
  c. ABS on vs off – only the "ABS off" data were included
  d. Weight Distribution – only the "as-is" data were included. The data obtained with a 50:50 weight distribution for the ½ ton pickup truck were not included.
  e. Surfaces – all were included. They were subdivided into categories.
  f. Temperatures - all were included. They were subdivided into categories.
  g. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(b) 2003 data collected at North Bay airport to investigate the effect of ABS on vs off [2] – data were included as follows:

  a. decelerometer types – all were included. However, most of the data were from ERDs.
  b. vehicles – all were included
  c. ABS on vs off – only the "ABS off" data were included.
  d. Surfaces – all were included. They were subdivided into categories.
  e. Temperatures - all were included. They were subdivided into categories.
  f. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

(c) 2003 data collected during CRFI Quality Assurance tests at five airports [2] – data were included as follows:

  a. decelerometer types – all of the data were from ERDs. Unreliable data (e.g., from TC's ERD Mk III) were not included.
  b. vehicles & operators – all data were included.
  c. airports, circuits & runs – all data were included.
  d. surfaces – all were included. They were subdivided into categories.
  e. CRFI values – averages for each relevant test case were included. Typically, these averages were based on about 15 individual decelerometer readings.

2.2 CRFIs on Bare Ice

CRFIs for bare ice are listed in Table 2.1. For reference, this table also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of available data, especially for the "<=-10°C" temperature case. Except for the ">=0°C" temperature case, the data quantity is considered to be sufficient to allow trends and conclusions to be established reliably.

(b) CRFI magnitudes – the 2002 & 2003 decelerometer data correlated reasonably well with the JWRFMP data.

(c) Effect of Temperature – the CRFIs were not strongly affected by temperature. The ">=0°C" temperature data may represent an exception to this statement. However, the data quantity for this case is quite small (i.e., only 6 observations).

Table 2.1 CRFIs Measured by Decelerometers on Bare Ice

Data Source		Surface Temperature Range			
		<= -10°C	<0°C to >-10°C	>=0°C	All Temps
JWRFMP [3][1]	Mean	0.12	0.11	0.20	0.12
	St Dev	0.0394	0.0463	0.1322	0.0544
	Max	0.21	0.29	0.45	0.45
	Min	0.08	0.05	0.08	0.05
	# of Obs	10	146	6	196[2]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.15	0.13	no data	0.14
	St Dev	0.0867	0.0384	no data	0.0665
	Max	0.47	0.24	no data	0.47
	Min	0.09	0.06	no data	0.06
	# of Obs	41	43	0	84

Notes:

1. These results do not include "rough ice" which is a separate surface category in the JWRFMP database.
2. The # of observations for all temperatures is more than the sum of the three temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.

2.2 CRFIs on Bare Packed Snow

CRFIs for bare ice are listed in Table 2.2. For reference, this table also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of data available for the "<=-15°C" temperature case. The data quantity for the ">-15°C" temperature case was not increased substantially by including the 2002 & 2003 test data. The data quantity is considered to be sufficient to allow trends and conclusions to be established reliably for all temperature cases.
(b) CRFI magnitudes – the 2002 & 2003 decelerometer data correlated reasonably well with the JWRFMP data.
(c) Effect of Temperature – the CRFIs were not strongly affected by temperature.

Table 2.2 CRFIs Measured by Decelerometers on Bare Packed Snow

Data Source	Surface Temperature Range			
		<= -15°C	>-15°C	All Temps
JWRFMP [3]	Mean	0.29	0.18	0.20
	St Dev	0.005	0.0635	0.0663
	Max	0.29	0.63	0.63
	Min	0.28	0.09	0.09
	# of Obs	4	138	186[1]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.22	0.25	0.23
	St Dev	0.0719	0.0377	0.0655
	Max	0.33	0.29	0.33
	Min	0.09	0.17	0.09
	# of Obs	24	9	33

Notes:

2. The # of observations for all temperatures is more than the sum of the two temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.

2.4 CRFIs on Sanded Ice and Sanded Packed Snow

CRFIs for sanded ice and sanded packed snow are listed in Tables 2.3 and 2.4, respectively. For reference, Table 2.3 also contains the corresponding values obtained from the JWRFMP for the ERD [3].

The following conclusions can be drawn:

(a) Data quantity – the 2002 & 2003 data have significantly increased the quantity of data available for sanded packed snow (as there are no data in the JWRFMP database for this case); the available data quantity is now considered to be sufficient to allow reliable analyses. With respect to sanded ice, although the 2002 & 2003 decelerometer test data have significantly increased the data quantity, the number of observations for sanded ice is still small which will limit the strength of the conclusions that can be drawn for this case.

(b) CRFI magnitudes for sanded ice – sanding increased the CRFI by about 0.1. Compare Tables 2.1 and 2.3.
(c) CRFI magnitudes for sanded packed snow – sanding did not increase the CRFI substantially. Compare Tables 2.2 and 2.4.
(d) Effect of Temperature for sanded ice – insufficient data are available to make firm statements.
(e) Effect of Temperature for sanded packed snow – higher CRFIs were measured for the warmer temperature case (i.e., >-15°C).

Table 2.3 CRFIs Measured by Decelerometers on Sanded Ice

Data Source		Surface Temperature Range			
		<= -10°C	<0°C to >-10°C	>=0°C	All Temps
JWRFMP [3][1]	Mean	0.30	0.26	0.23	0.24
	St Dev	no data[3]	0.0929	no data[3]	0.0513
	Max	no data[3]	0.34	no data[3]	0.34
	Min	no data[3]	0.16	no data[3]	0.16
	# of Obs	1	3	1	12[2]
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.23	0.31	no data	0.25
	St Dev	0.0183	0.0629	no data	0.0487
	Max	0.25	0.38	no data	0.38
	Min	0.20	0.25	no data	0.20
	# of Obs	12	4	0	16

Notes:
1. These results do not include "rough ice" which is a separate surface category in the JWRFMP database.
2. The # of observations for all temperatures is more than the sum of the three temperature subsets as not all CRFI data in the JWRFMP database have surface temperature data associated with them.
3. Only one observation.

Table 2.4 CRFIs Measured by Decelerometers on Sanded Packed Snow

Data Source	Surface Temperature Range			
		<= -15°C	>-15°C	All Temps
JWRFMP [3][1]	Mean	no data	no data	no data
	St Dev	no data	no data	no data
	Max	no data	no data	no data
	Min	no data	no data	no data
	# of Obs	0	0	0
Decelerometer Tests in 2002 & 2003 [1], [2]	Mean	0.26	0.37	0.35
	St Dev	0.0584	0.0845	0.0811
	Max	0.31	0.53	0.53
	Min	0.14	0.25	0.14
	# of Obs	12	61	73

Notes:
1. There are no data in the JWRFMP database for sanded packed snow.

2.5 CRFIs on Surfaces With Loose Snow on Top – Effect of Snow Depth

2.5.1 CRFIs for Loose Snow on Pavement

The 2002 & 2003 decelerometer tests [1], [2] provided 54 data points. This is a significant addition to the 121 observations obtained from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.1. Snow depths less than 3 mm (1/8") caused a substantial drop in CRFI. The CRFI was not affected by a snow depth variation from 3 to 6 mm (1/8 to ¼"). This trend shows that only a small amount of snow on the pavement will degrade its CRFI such that it is effectively "snow" rather than bare pavement.

For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.2. Although the JWRFMP data span a much wider range of snow depths, they also support the above observation. The 2002 & 2003 decelerometer data assist in defining the relationship for small snow depths.

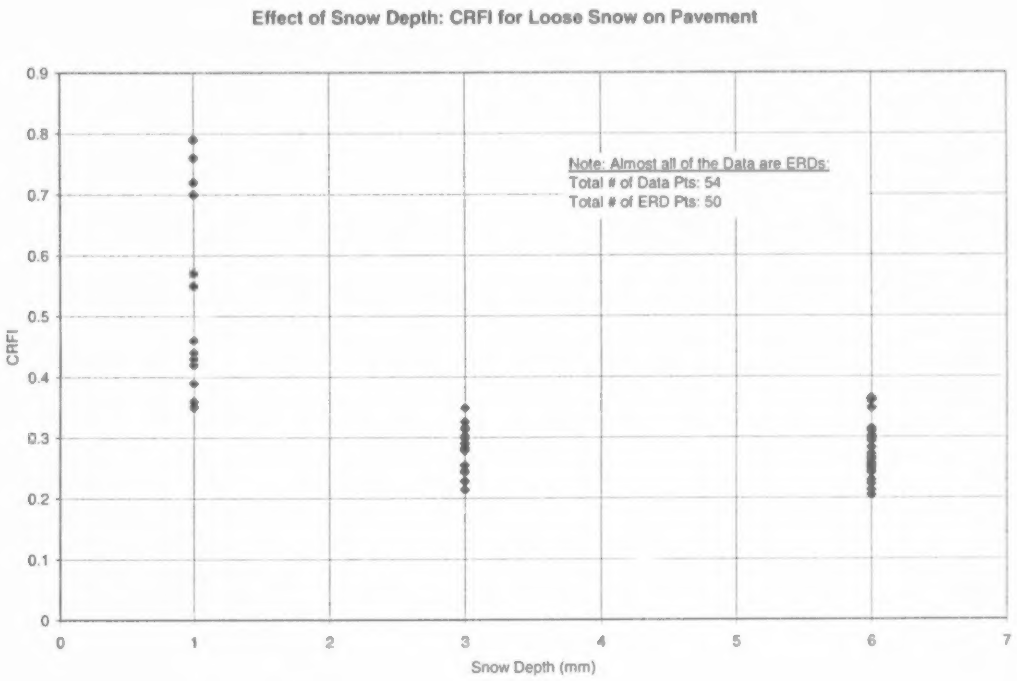


Figure 2.1
Effect of Snow Depth: 2002 & 2003 Decelerometer Data for Loose Snow on Pavement

Friction Coefficient Measured by the ERD for Loose Snow on Pavement

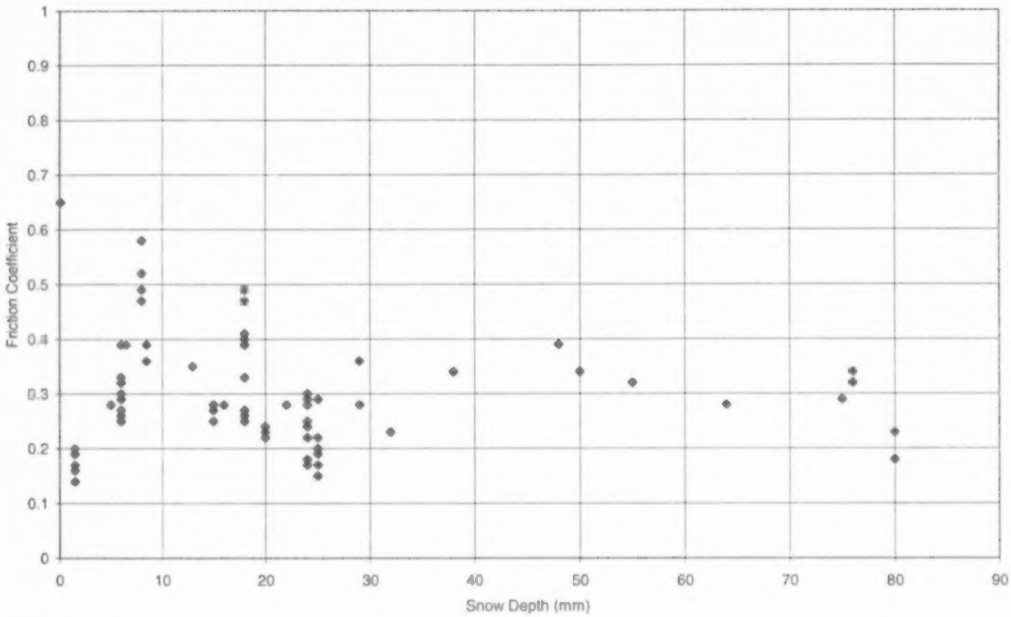
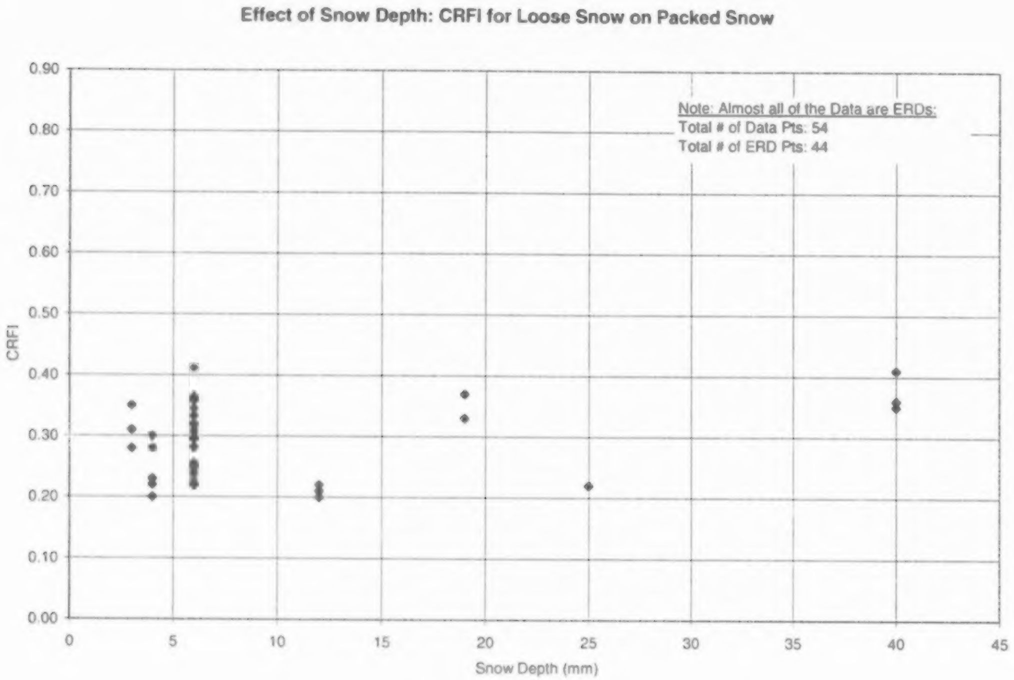


Figure 2.2 Effect of Snow Depth: JWRFMP Data for Loose Snow on Pavement [3]

2.5.2 CRFIs for Loose Snow on Packed Snow

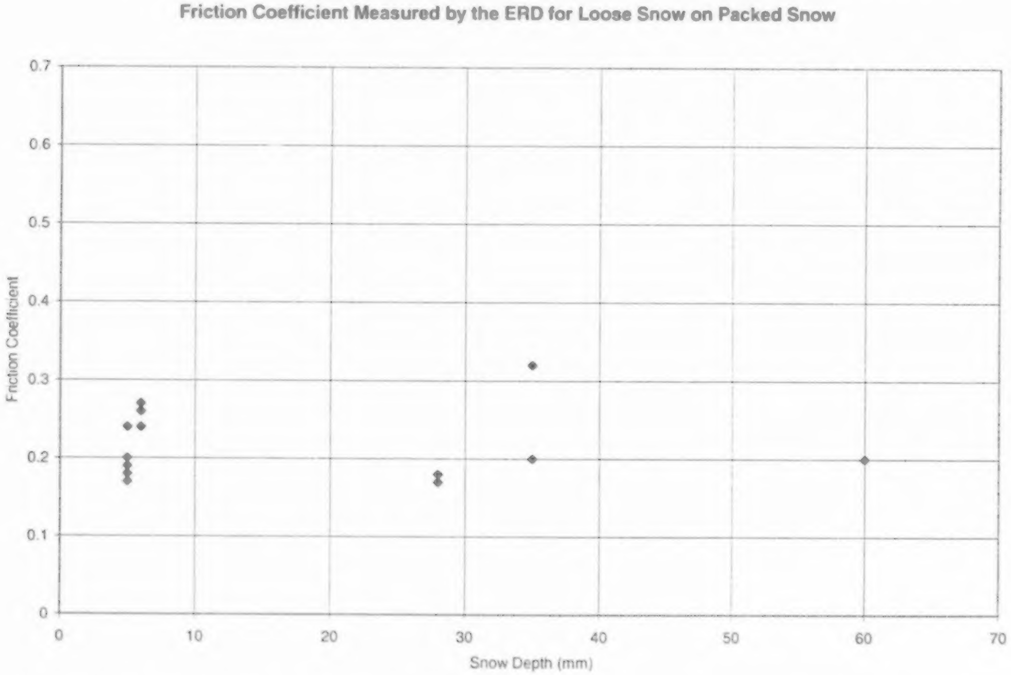
The 2002 & 2003 decelerometer tests [1], [2] provided 54 data points. This is a significant addition to the 27 observations obtained from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.3. For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.4. Both data sets indicate that CRFIs for snow-covered packed snow are substantially affected by snow depth, for depths up to about 40 mm.



Effect of Snow Depth: CRFI for Loose Snow on Packed Snow

Figure 2.3
Snow Depth Effect: 2002 & 2003 Decelerometer Data for Snow on Packed Snow



Friction Coefficient Measured by the ERD for Loose Snow on Packed Snow

Figure 2.4 Snow Depth Effect: JWRFMP Data for Loose Snow on Packed Snow [3]

2.5.3 CRFIs for Loose Snow on Ice

The 2002 & 2003 decelerometer tests [1] [2] provided some more data points (i.e., 15) to add to the 95 observations available from the JWRFMP database [3].

The trend indicated by the 2002 & 2003 decelerometer data is shown in Figure 2.5. For comparison, the trend indicated from the JWRFMP data [3] is shown in Figure 2.6. The JWRFMP data indicate that the CRFIs measured by decelerometers increase steadily with snow depth, although the relationship is scattered. The 2002 & 2003 decelerometer test data would fall within the general data band from the JWRFMP.

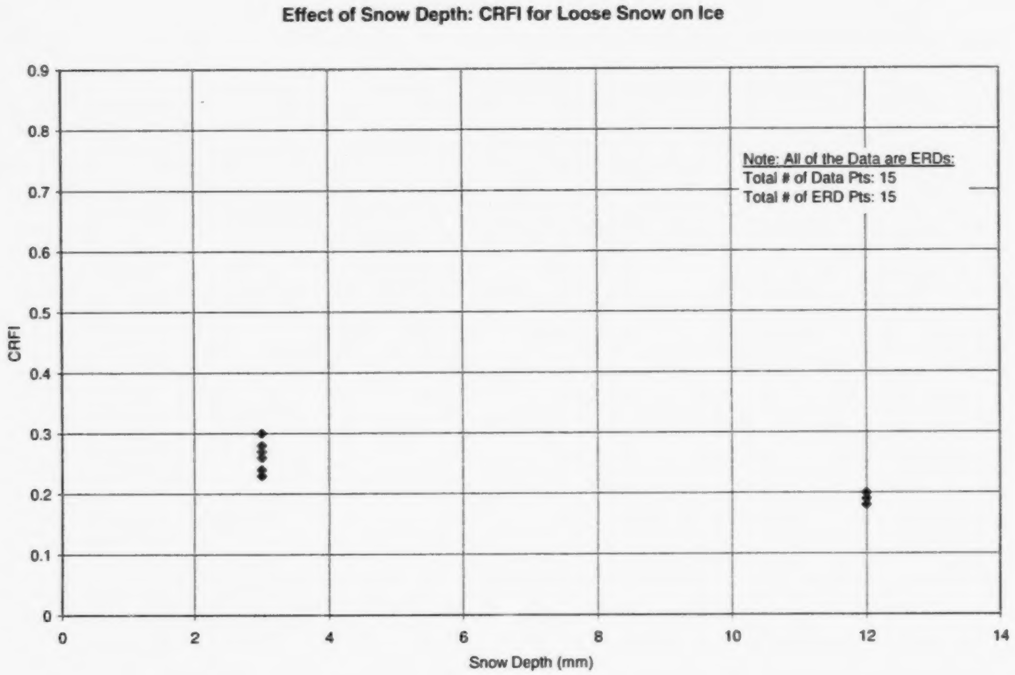


Figure 2.5
Effect of Snow Depth: 2002 & 2003 Decelerometer Data for Loose Snow on Ice

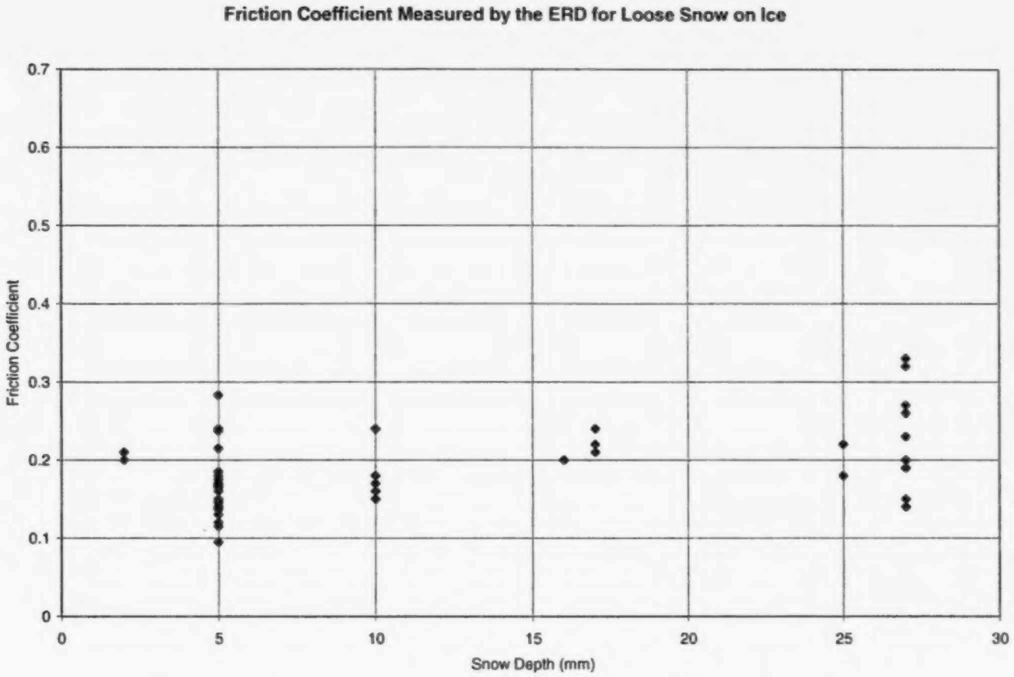


Figure 2.6 Effect of Snow Depth: JWRFMP Data for Loose Snow on Ice [3]

3.0 Concluding Remarks

This memo was sent to mainly present information to assist decision-making for the remainder of the study. The following comments can be made:

(c) Outliers and establishing CRFI ranges - the combined approach (of using both reality checks and some fraction of the distribution) produces reasonable results. Both the reality limits and the fraction need to be selected with care as they both affect the results. The key question that needs to be addressed is:

- What degree of variability should the guidelines in the AIP reflect?

We seek your input regarding this.

(d) 2002 & 2003 Decelerometer Test Data – these data augment the previous analyses considerably. We suggest that all subsequent analyses should be done using the combined data set (i.e., the JWRFMP database plus the 2002 & 2003 decelerometer test program results).

4.0 References

[1] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP13980E.

[2] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP# to come.

[3] Comfort, G., 2003, Effect of Surface Conditions on the Friction Coefficients Measured on Winter Surfaces, Transport Canada report, TP# to come.

APPENDIX C.2

MEETING NOTES AND MINUTES (JANUARY 28, 2004)

CRFI/AIP Information Update Project (PWGSC Contract # T8200-033527/001/MTB)

Meeting Notes and Minutes

Date: **Jan. 28, 2004**
By: **G. Comfort, BMT Fleet Technology Ltd.**
Meeting Attendees: **A. Boccanfuso**
J. Martin
D. Morra
A. Krol
M. Farha
P. Lamont
P. Carson
G. Comfort

Introduction

A meeting was held with Transport Canada representatives on Jan. 28, 2004. A presentation was shown by G. Comfort. This is copied in Appendix A. The meeting was held to:

(a) update Transport Canada on FTL's progress regarding the above study.
(b) obtain guidance and direction in general, and; specifically regarding:
    a. the surfaces that should be included in the analyses and the AIP update
    b. the ranges of CRFIs that should be included

Key Points

(a) Inclusion of Aircraft Braking Performance Indication - the updated AIP should not attempt to relate aircraft braking performance (e.g., nil, poor, fair, good) with the CRFIs shown in the table (as depicted in slide 10 of FTL's presentation – Appendix A). The table to be included in the updated AIP should only provide a range of CRFIs for the selected surfaces.

(b) Range of CRFI values to be Included – there was considerable discussion. It was generally felt that the AIP table should be generally aimed towards providing the most likely range of CRFIs for a given surface rather than the extreme range that might be encountered. It was decided that:
    a. J. Martin will consider this further, and contact John Croll. They will review the basis on which the current landing distance tables were developed, as this has already accounted for some variability in the surface's CRFI. They will contact FTL and other Transport Canada representatives once this is complete.
    b. FTL should do some more analyses by:
        i. Using the "reality limits" shown at the meeting (Slide 21 – Appendix A) to filter out outliers
        ii. Establishing upper and lower-range limits by including 67% of the area under the distribution. This is equivalent to the mean +/- 1 standard deviation for a normal distribution.

(c) Surfaces to be Included – it was generally agreed that the surfaces listed by D. Morra (slide 10 of FTL's presentation – Appendix A) should be the ones included in the study, except as follows:

a. Wet – no CRFIs should be given for wet as this is speed-dependent.
b. Dry – although this surface is to be included, an analysis of dry pavement CRFIs is beyond the scope of this study, as very little data are available from the winter testing regarding this.
c. Loose snow on pavement – it was noted that this is depth-dependent for snow depths up to about 5 mm. CRFI information in the table should be applicable to snow depths greater than about 5mm. A note should be added regarding the effect of snow depth.

(d) Effect of Temperature – FTL presented information (based on analyses of the JWRFMP data) showing that CRFIs are not strongly related to surface temperature, if at all. FTL suggested that the table should not provide CRFIs for different surface temperature ranges, but rather CRFIs for all surface temperatures, except for cases right at the melting point where it was thought CRFIs could be affected by phase changes (producing a water film). There was general agreement with this. It was pointed out that the available data are inadequate to define CRFIs for cases right at the melting point, and a note should be added to this effect.

(e) SFT Data to be Analyzed – more SFT data are available than were used in the analyses to date. FTL should analyze the full data set, which includes the TC SFT'79, the TC SFT Turbo, and the SFT 900. FTL will investigate this and contact Alice Krol.

(f) Comments Regarding the Reasons for CRFI Variations – these are valuable and should be provided by FTL.

APPENDIX A

PRESENTATION SHOWN AT MEETING

Update CRFIs in the Aeronautical Information to Pilots (AIP)

By: G. Comfort, BMT Fleet Technology Ltd

Jan. 28 2004

Project Sponsors and Technical Authorities:
A. Boccanfuso, Transportation Development Centre
D. Morra and others, Aerodrome Safety, Transport Canada

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PROJECT OBJECTIVES

- Effect of Surface Cond'ns: Obtain Better Understanding
- AIP Update: Assess the Req'd Information; and Obtain It
  - Interactive Effort With Transport Canada
  - Which Devices?
    - AIP: Based on CRFI – Decelerometers
    - General Understanding: Decelerometers; IMAG & TC SFT
  - Different Temperature Ranges ? – to be discussed
  - Surfaces ? – Study limited to "Winter" Surfaces" – exact list to be discussed
  - What Range of CRFIs to be included ? – to be discussed
  - Brief Comments Regarding What Causes CRFI Variations ? – to be discussed

SOME OBJECTIVES FOR THIS MEETING

- #1 – General: Obtain Guidance and Direction
- #2 – Specific: Which Surfaces Should be Included?
- #3 – Specific: Ranges of CRFIs to be Included in the AIP
  - **CRFIs from the JWRFMP span a wide range – shouldn't put the full range in the AIP**
  - **Have investigated various methods for selecting a range – Tried:**
    - Step#1 – Implement "Reality" Checks – Remove CRFIs outside the "reality" limits
    - Step#2 – Only Include CRFIs from Main Body of Distribution
      - Mean +/- 1 or 2 Standard Deviations. Won't work because distributions usually are not normal – will get negative CRFIs
      - Applied Limits corresponding to 67% & 96% of the Area under the curve – Equivalent to mean +/- 1 or 2 SDs for a normal distribution
  - **Request: Obtain Guidance & Direction Regarding**
    - Suggested Approach
    - How much CRFI Variation Should the AIP Reflect?
    - What "Reality Limits" Should be Used?

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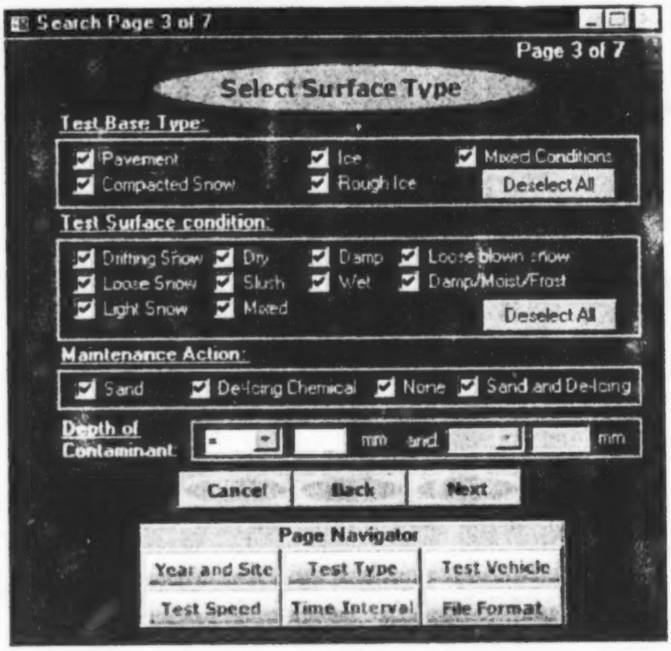
INFORMATION SOURCES

- Test Programs:
  - Joint Winter Runway Friction Measurement Program (JWRFMP) conducted since 1996
    - **Exploratory Study Done Last Year to Investigate the Effect of Surface Conditions on CRFIs – Done by Querying the JWRFMP Database**
      - Device Vs Surface
      - Device Pairs Vs Surface
  - Decelerometer Tests in 2002 & 2003
    - **2002 – North Bay Airport - Effect of Vehicle Type**
    - **2003:**
      - North Bay Airport ABS On vs Off
      - 5 Airports in Northern Ontario. Blazer vs Site System

SURFACE CONDITIONS IN THE DATABASE


Search Page 3 of 7
Page 3 of 7
Select Surface Type
Deselect All
Deselect All
Cancel
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Next
Page Navigator
Year and Site
Test Type
Test Vehicle
Test Speed
Time Interval
File Format

Test Base Type:

☑ Pavement ☑ Ice ☑ Mixed Conditions
☑ Compacted Snow ☑ Rough Ice

Test Surface condition:

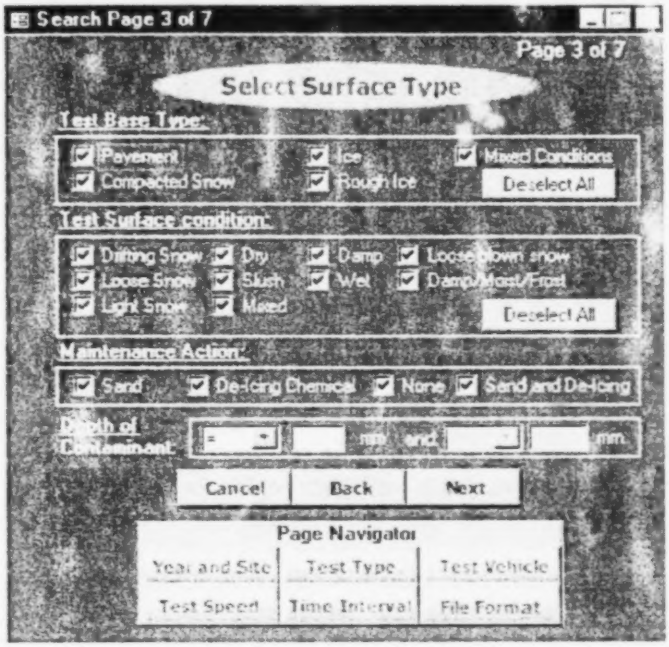
☑ Drifting Snow ☑ Dry ☑ Damp ☑ Loose blown snow
☑ Loose Snow ☑ Slush ☑ Wet ☑ Damp/Moist/Frost
☑ Light Snow ☑ Mixed

Maintenance Action:

☑ Sand ☑ De-Icing Chemical ☑ None ☑ Sand and De-Icing

Depth of Contaminant: = mm and mm

SURFACE CONDITIONS IN THE DATABASE



Search Page 3 of 7

Page 3 of 7

Select Surface Type

Test Base Type:

☑ Pavement ☑ Ice ☑ Mixed Conditions
☑ Compacted Snow ☑ Rough Ice

Test Surface condition:

☑ Drifting Snow ☑ Dry ☑ Damp ☑ Loose blown snow
☑ Loose Snow ☑ Slush ☑ Wet ☑ Damp/Moist/Frost
☑ Light Snow ☑ Mixed

Maintenance Action:

☑ Sand ☑ De-Icing Chemical ☑ None ☑ Sand and De-Icing

Depth of Contaminant: = mm and mm.

Deselect All
Deselect All
Cancel
Back
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Page Navigator
Year and Site
Test Type
Test Vehicle
Test Speed
Time Interval
File Format

SEARCH PARAMETERS USED FOR THE JWRFMP: SURFACES

- **Bare Ice:**
  - >= 0 deg C; 0 deg C to –10 deg C ; <= -10 deg C
  - Bare Ice Including or not including Rough Ice
  - Sanded or Not
- **Bare Packed Snow**
  - >-15 deg C; <= -15 deg C
- **Snow**
  - on Pavement; on Packed Snow; On Ice
  - All depths & Less than 10 mm
  - Divided by Surface Temperature
- **Bare Pavement**
- **Wet or Damp Pavement**
- **Slush on any Base Surface**

SEARCH PARAMETERS USED FOR TH E JWRFMP DATA

- Devices Analyzed
  - ERD
  - TC SFT'79
    - Configuration 3
    - All Configurations
  - **IMAG Force & IMAG Torque**
    - Configurations 3 & 7
    - All Configurations

- Speeds – all speeds
- 100 m vs Whole Track – Used Whole Track Data
- Time Interval Between Readings – Included all data

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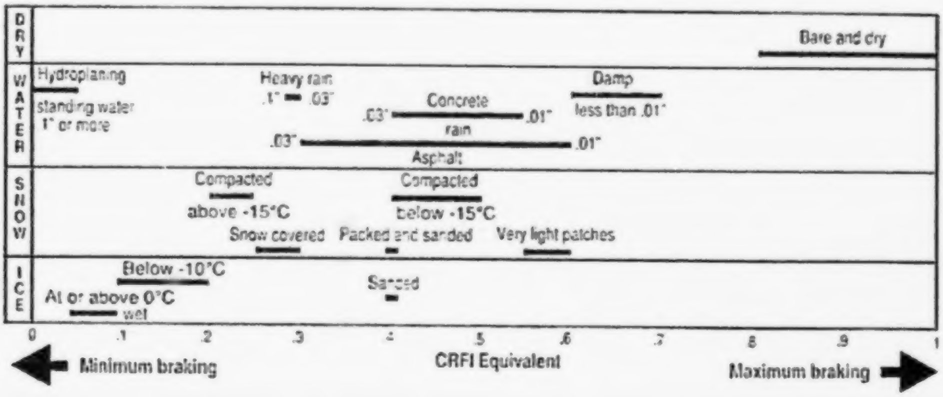
SEARCH PARAMETERS USED FOR THE DECELEROMETER TEST DATA

- Devices – Included All Decels (ERD Mk III, ERD Mk II, Tapley, Bowmonk) – But:
  - Almost All of the data were from ERDs
- Vehicles – All were included
- ABS On vs Off – Only the ABS Off Data
- Weight Distribution – Only the “as-is” data
- Surfaces – All data included as follows:
  - They were within the range where decels are considered reliable
  - Data for surfaces grouped according to various classifications
- Speeds – All data included
  - 2002 Tests: 40 km/hr
  - 2003 Tests: 50 km/hr
- Averages & Whole Track – Used Whole Track Data
  - Averages typically based on 15 or more decel readings
  - Similar to usage of JWRFMP data, which was also based on averages

EFFECT OF SURFACE CONDITION: CRFIs IN THE AIP NOW

RUNWAY SURFACE CONDITION (RSC) AND CRFI EQUIVILENT



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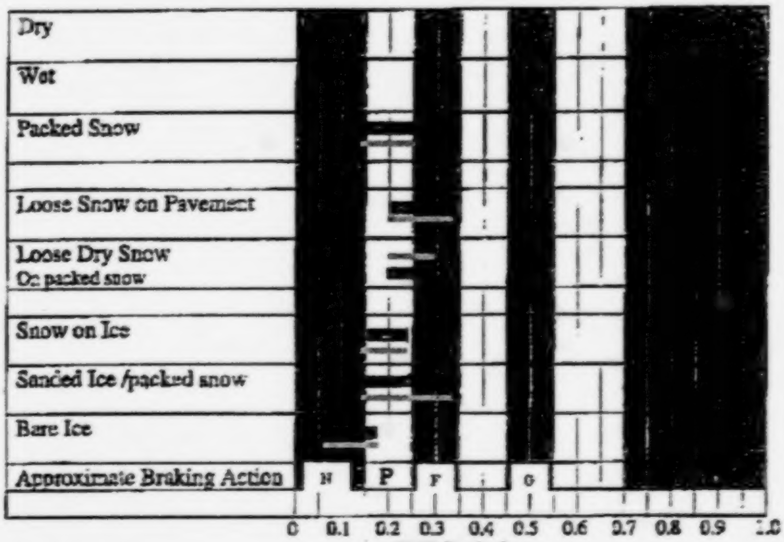
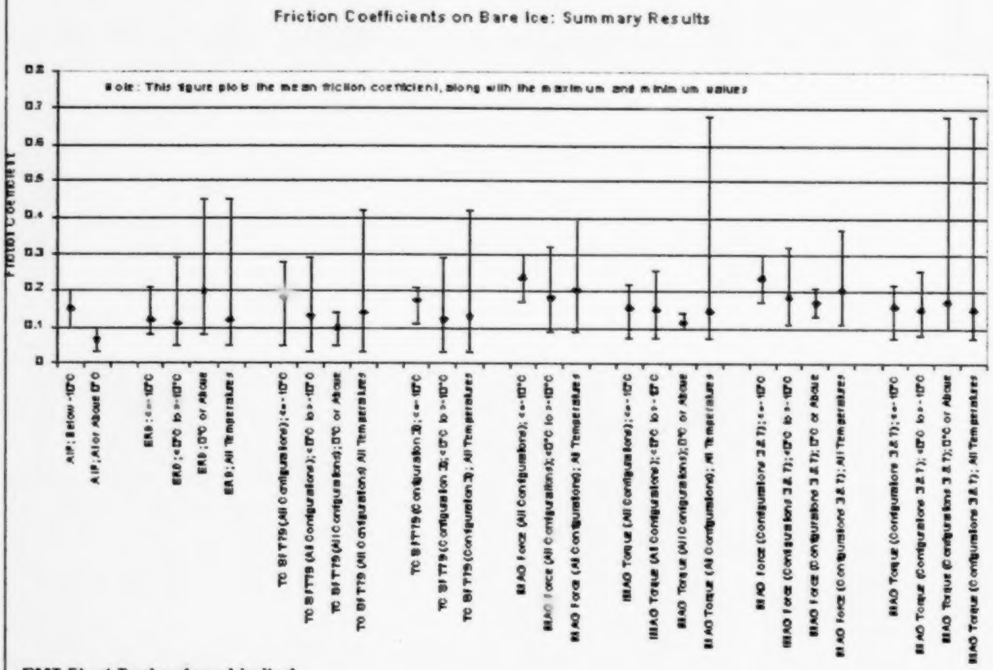
CRFIs by SURFACE CONDITION: SUGGESTION BY D. MORRA

Runway Surface Condition and CRFI Equivalent
(Edited Jan. 26/01)



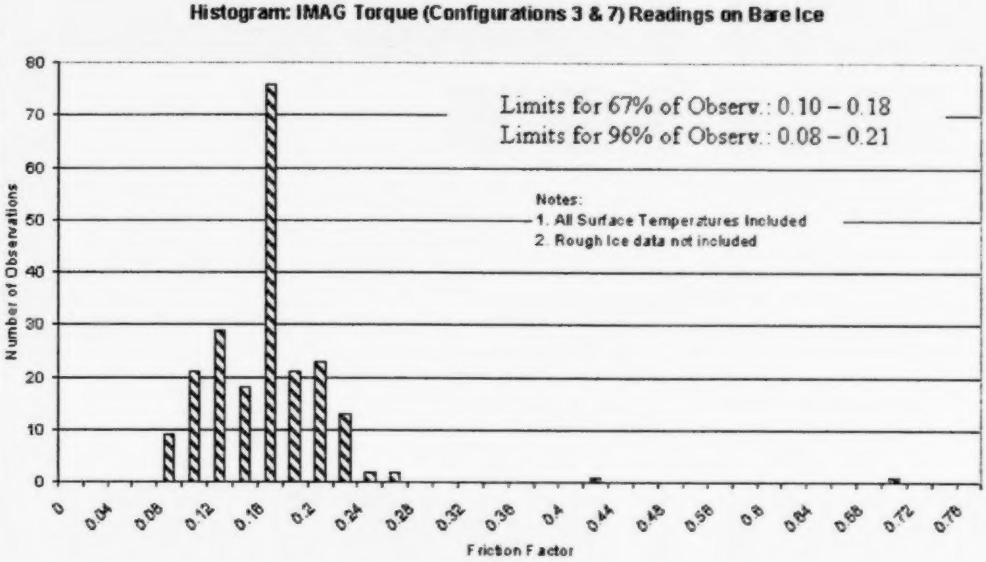
FRICTION ON BARE ICE: JWRFMP DATA



FRICTION ON ICE: JWRFMP & DECEL DATA

JWRFMP/ Decel Data	Bare Ice			Sanded Ice		
	Mean	Max; Min	# Obs	Mean	Max; Min	# Obs
<=-10°C	0.12 / 0.15	0.21;0.08/ 0.47;0.09	10/ 41	0.3 / 0.23	n/a; n/a / 0.25; 0.20	1 / 12
<0° to >– 10°C	0.11/ 0.13	0.29;0.05/ 0.24;0.06	146/ 43	0.26 / 0.31	0.34;0.16 / 0.38;0.25	3 / 4
>=0°C	0.2/ n/a	0.45;0.08/ n/a;n/a	6/ 0	0.23 / n/a	n/a; n/a / n/a; n/a /	1 / 0
All Temps	0.12/ 0.14	0.45;0.05/ 0.47/0.06	196/ 84	0.24 / 0.25	0.34;0.16 / 0.38;0.20	12 / 16

BARE ICE FRICTION (JWRFMP): IMAG TORQUE



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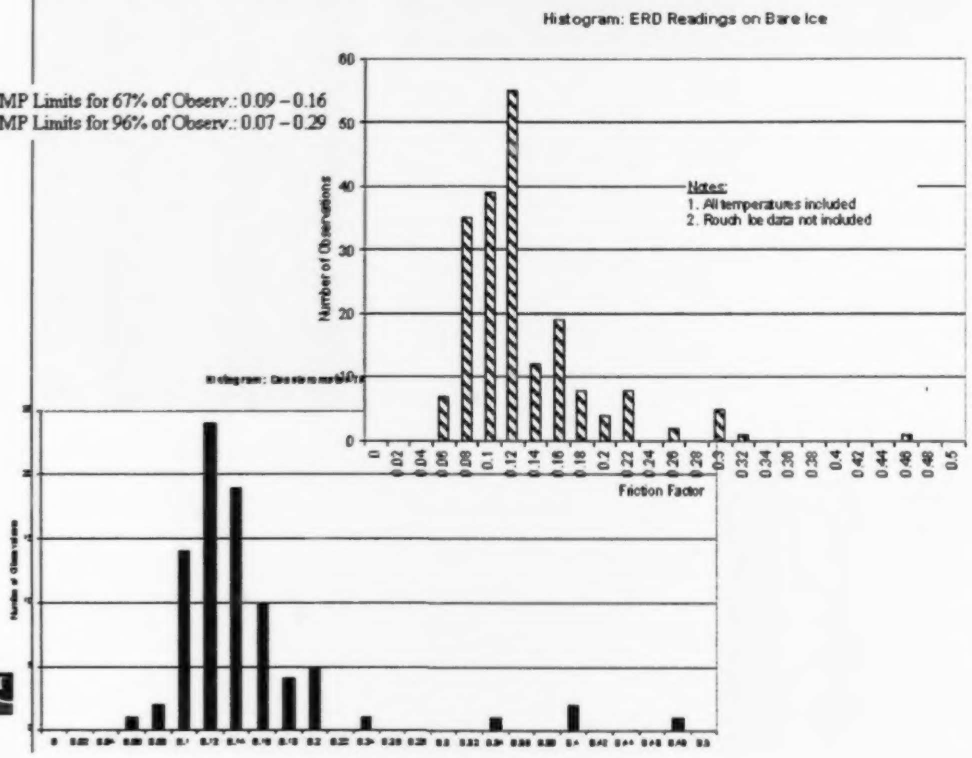
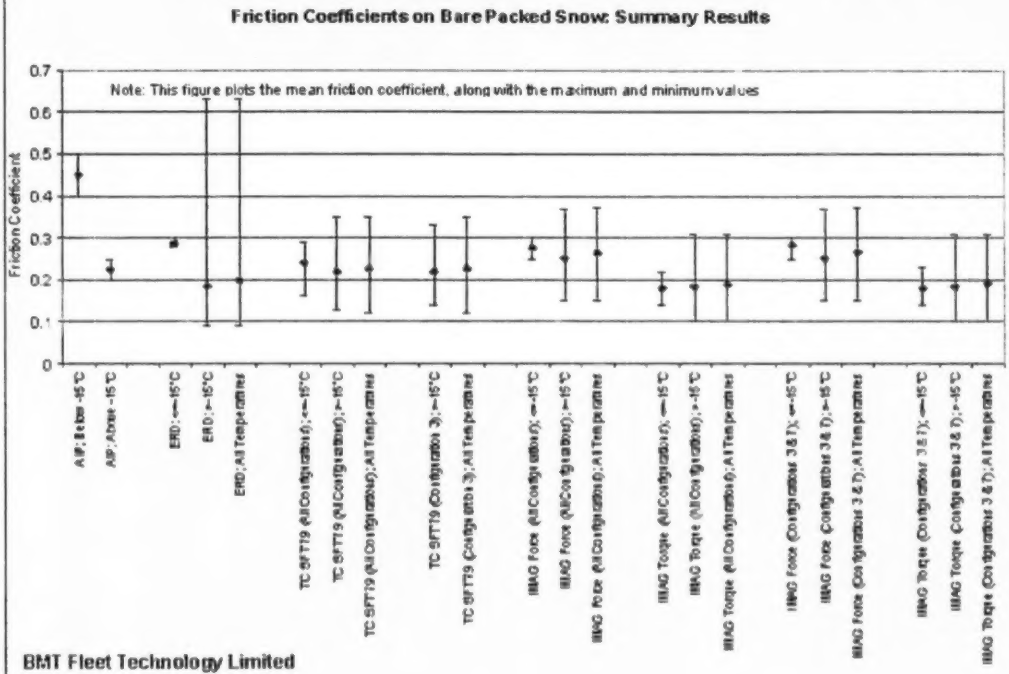
FRICTION ON BARE ICE: JWRFMP & DECELS

JWRFMP Limits for 67% of Observ.: 0.09 – 0.16
JWRFMP Limits for 96% of Observ.: 0.07 – 0.29



FRICTION ON BARE PACKED SNOW



Friction Coefficients on Bare Packed Snow: Summary Results

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FRICTION ON PACKED SNOW:
JWRFMP & DECEL DATA

JWRFMP/ Decel Data	**Bare Packed Snow**			**Sanded Packed Snow**		
	Mean	Max; Min	# Obs	Mean	Max; Min	# Obs
<=-15°C	0.29 / 0.22	0.29;0.28/ 0.33;0.09	4/ 24	n/a / 0.26	n/a; n/a / 0.31; 0.14	0 / 12
>-15°C	0.18/ 0.25	0.63;0.09/ 0.29;0.17	138/ 9	n/a / 0.37	n/a; n/a / 0.53; 0.25	0 / 61
All Temps	0.20/ 0.23	0.63;0.09/ 0.33/0.09	186/ 33	n/a / 0.35	n/a; n/a / 0.53;0.14	0 / 73

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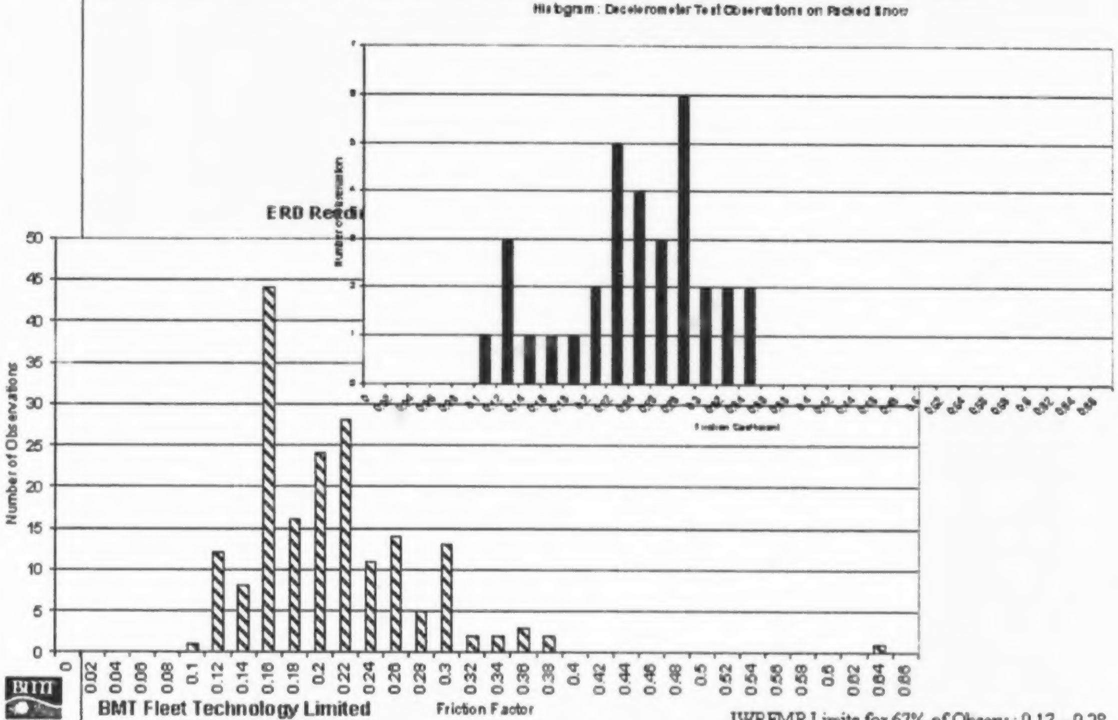
FRICTION ON PACKED SNOW: JWRFMP & DECELS



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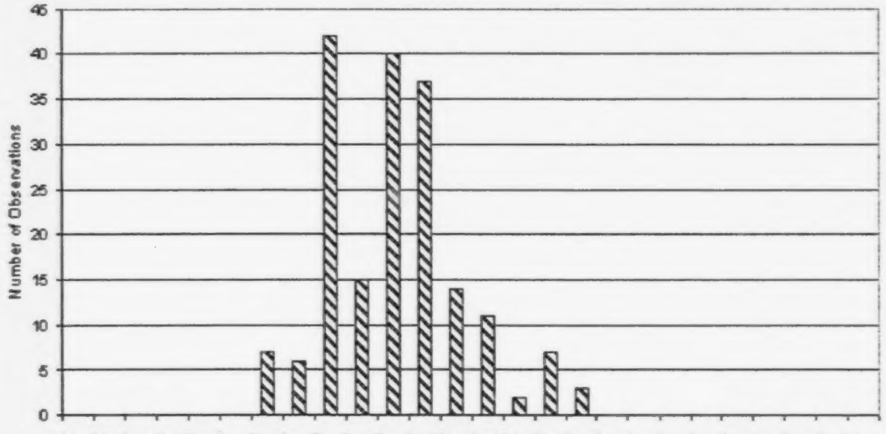
JWRFMP Limits for 67% of Observ.: 0.17 – 0.28
JWRFMP Limits for 96% of Observ.: 0.15 – 0.38

BARE ICE FRICTION (JWRFMP): IMAG TORQUE

Limits for 67% of Observ.: 0.17 – 0.26
Limits for 96% of Observ.: 0.16 – 0.32

IMAG Torque (Configurations 3 & 7) Readings on Bare Packed Snow: JWRFMP



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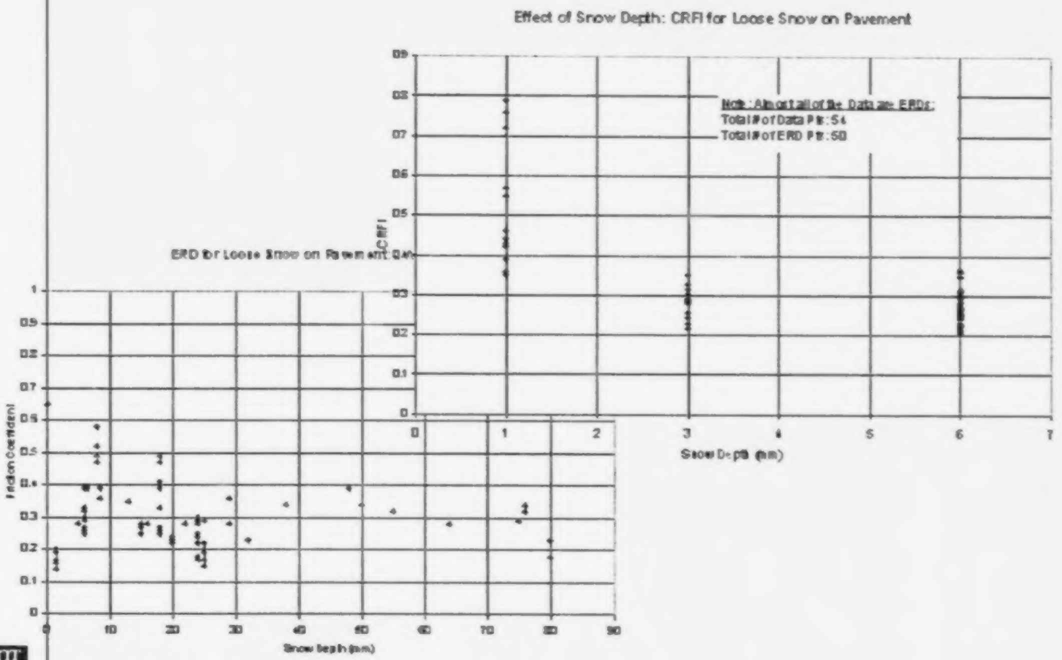
SNOW DEPTH: LOOSE SNOW ON PAVEMENT



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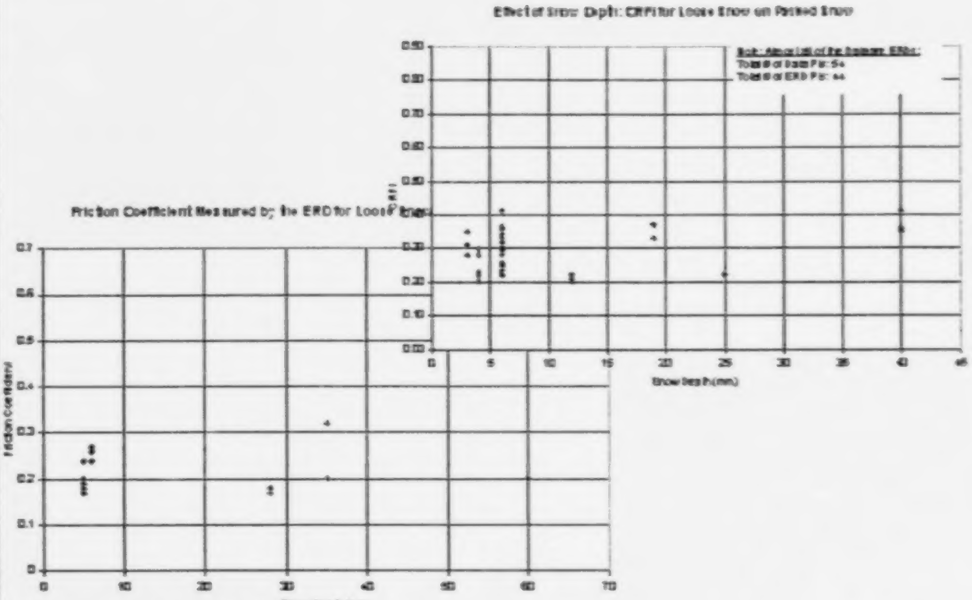
SNOW DEPTH: LOOSE SNOW ON PACKED SNOW



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RANGES OF CRFIS TO BE INCLUDED

- Step # 1 – Apply "Reality "Limits"
- Step # 2 – Calculate Limits Based on Statistics

What Should the "Reality Limits" Be?

Surface	Lower Limit	Upper Limit
Ice	No Limit	0.3
Sanded Ice	0.1	0.4
Packed Snow	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Pavement	0.1	0.4
Loose Snow on Packed Snow	0.1	0.4

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PROJECT OBJECTIVES (REPEAT)

- Effect of Surface Cond'ns: Obtain Better Understanding
- AIP Update: Assess the Req'd Information; and Obtain It

  - Interactive Effort With Transport Canada
  - Which Devices?
    - AIP: Based on CRFI – Decelerometers
    - General Understanding: Decelerometers; IMAG & TC SFT
  - Different Temperature Ranges ? – FTL sugg'n: Don't Differentiate by Temperature
  - Surfaces ? – Study limited to "Winter" Surfaces" – as per Dominic's List?
  - What Range of CRFIs to be included ? – to be discussed
  - Brief Comments Regarding What Causes CRFI Variations ? – to be discussed

BMT Fleet Technology Limited

CONCLUSIONS

- Surfaces to Be Included
- Ranges of CRFIs to be Included
- Effect of Snow Depth

APPENDIX C.3

CRFI UPDATES FOR THE AIP:
FURTHER ANALYSIS OF OUTLIERS & ASSESSMENT OF "REALITY LIMITS"

April 20, 2004
BMT FTL File: 5699

To: Angelo Boccanfuso, Transportation Development Centre
Dominic Morra, Transport Canada
J. Martin, Transport Canada
A. Krol, Transport Canada
M. Farha, Transport Canada
P. Lamont, Transport Canada
P. Carson, Transport Canada
J. Croll, National Research Council

From: George Comfort BMT Fleet Technology Ltd.

Re: CRFI Updates for the AIP:

Further Analysis of Outliers & Assessment of "Reality Limits"

This memo is sent to follow up the above, which is one of the action items we had from our Jan. 28 meeting. It addresses the comments made by Dominic Morra regarding our first submission, which was made on March 31, 2004.

Review and Approach

As you know, the issue of "reality limits" and the treatment of CRFI outliers was discussed in some detail during our Jan. 28 meeting. I proposed the following "reality limits" as initial values (Table 1). As there appeared to be general agreement regarding them, I used them for the analyses presented here.

Table 1 Proposed "Reality Limits" for CRFIs on Various Surfaces

Surface	Lower CRFI Limit	Upper CRFI Limit
Ice	No Limit	0.3
Sanded Ice	0.1	0.4
Packed Snow	0.1	0.4
Sanded Packed Snow	0.1	0.5
Loose Snow on Pavement	0.1	0.4
Loose Snow on Packed Snow	0.1	0.4

Analyses weredone for the following surfaces:
(a) bare ice
(b) bare packed snow
(c) loose snow on pavement – for this case, the analyses only included data where the snow thickness ranged between 3 mm and 25 mm.

The CRFI data were analyzed as follows:

(a) Devices – the analyses were done for decelerometers. The vast majority of the available data for decelerometers are for ERDs.

(b) Data sources – the following data sources were combined:

   a. all data from the JWRFMP, as described in our Jan. 14 memo and in [1]

   b. data collected during the 2002 test program using decelerometers [2], as described in our Jan. 14 memo

   c. data collected during the 2003 test program using decelerometers [3], as described in our Jan. 14 memo

(c) surface temperatures – all surface temperatures were combined.

Results: Bare Ice

The results are plotted as follows:

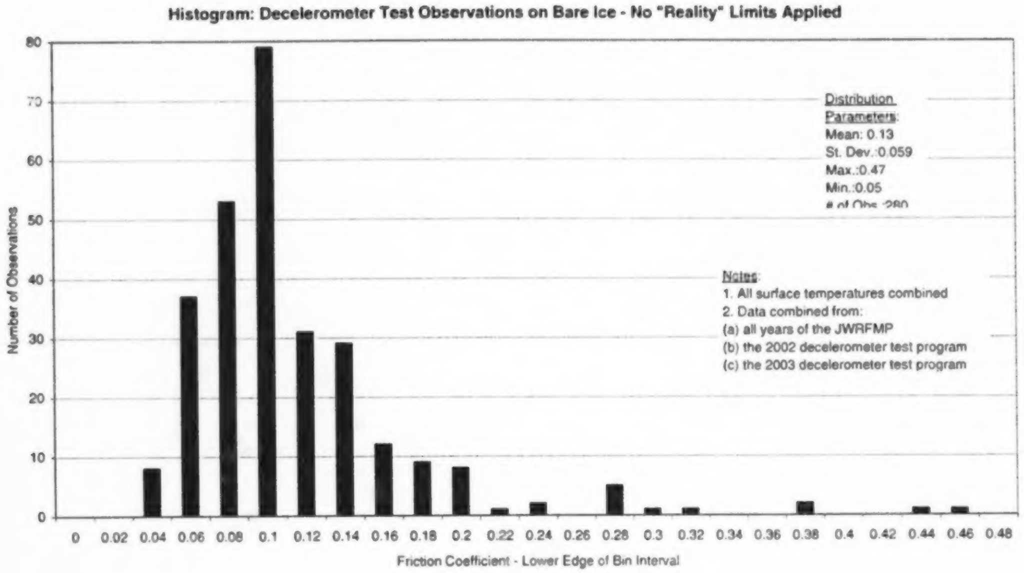
(a) Figure 1 – histogram for the full data set without the application of "reality limits"
(b) Figure 2 – histogram for the full data set with the application of "reality limits"
(c) Figure 3 – probability density function for the full data set with the application of "reality limits"

It is evident that:

(a) the removal of outliers had little effect on the overall distribution or its parameters (e.g., mean, standard deviation) as only 6 of 280 observations were removed from the distribution. This is considered reasonable as the intent of removing outliers was not to change the distribution. However, the maximum CRFI was reduced significantly by removing the outliers, which again shows that the intended result was achieved.

(b) CRFI limits for +/- 33.5% of the pdf area from the mean (which would be equivalent to +/- 1 sd for a normal distribution) – CRFI limits were calculated to be 0.095 to 0.22 for this case (Figure 3). It can be seen that this has skewed the CRFI range to the right (to higher CRFIs) as the distribution is not normal (Figure 3). This is not considered to be advisable.

(c) CRFI limits for +/- 33.5% of the pdf area from the median – CRFI limits were calculated to be 0.08 to 0.16 for this case (Figure 3). It can be seen that this approach produces a range that is more representative of the overall distribution. This is considered to be advisable.

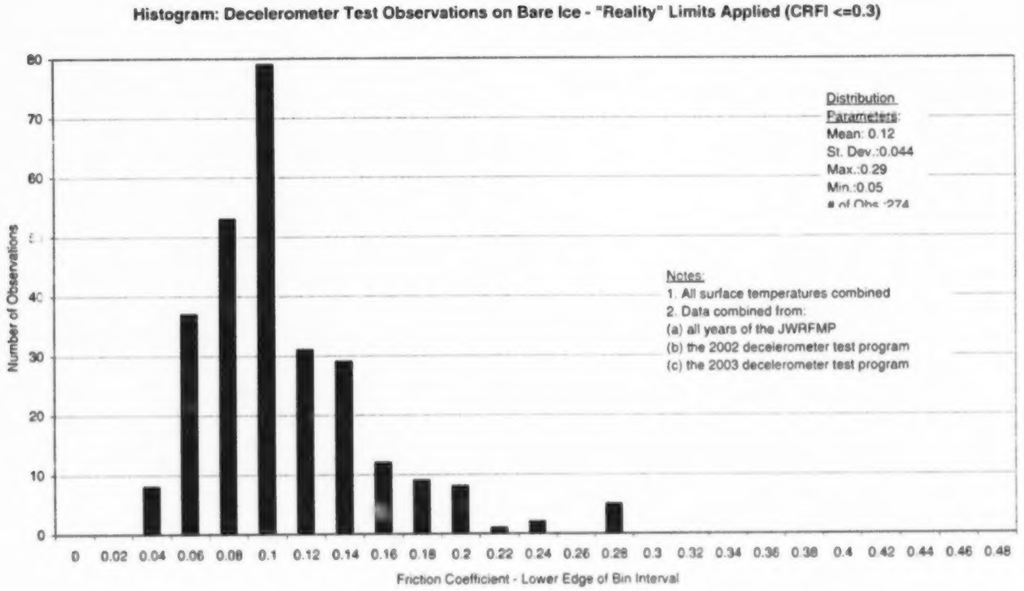


Histogram: Decelerometer Test Observations on Bare Ice - No "Reality" Limits Applied

Distribution Parameters:
Mean: 0.13
St. Dev.:0.059
Max.:0.47
Min.:0.05
# of Obs.:280

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Figure 1

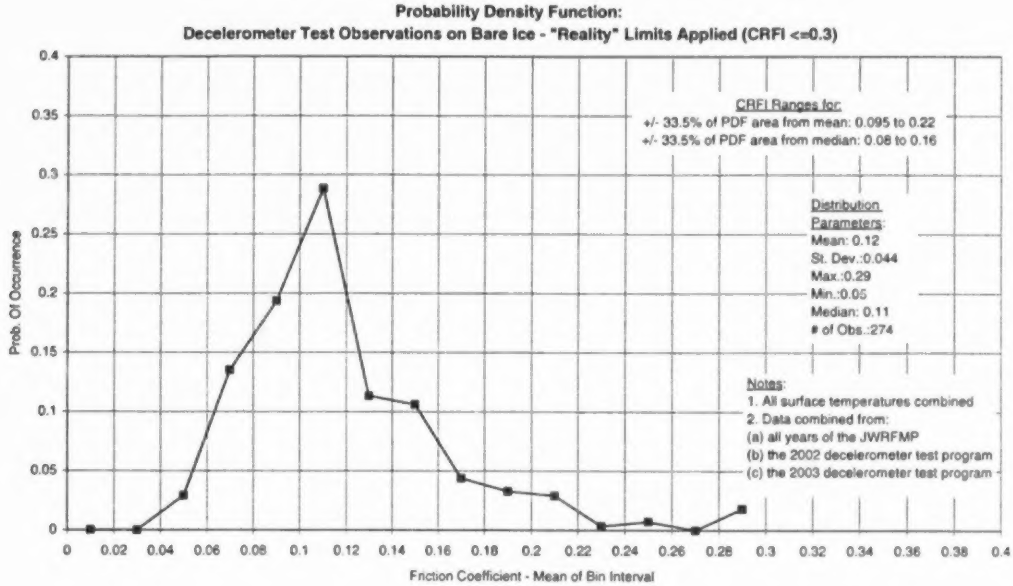


Histogram: Decelerometer Test Observations on Bare Ice - "Reality" Limits Applied (CRFI <=0.3)

Distribution Parameters:
Mean: 0.12
St. Dev.:0.044
Max.:0.29
Min.:0.05
# of Obs.:274

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Figure 2



Probability Density Function:
Decelerometer Test Observations on Bare Ice - "Reality" Limits Applied (CRFI <=0.3)

Figure 3

Results: Bare Packed Snow

The results are plotted as follows:
(a) Figure 4 – histogram for the full data set without the application of "reality limits"
(b) Figure 5 – histogram for the full data set with the application of "reality limits"
(c) Figure 6 – probability density function for the full data set with the application of "reality limits"

It is evident that:

(a) the removal of outliers had little effect on the overall distribution or its parameters (e.g., mean, standard deviation) as only 3 of 219 observations were removed from the distribution. This had the desired intent of not changing the distribution. However, the maximum CRFI was reduced significantly by removing the outliers, which again shows that the intended result was achieved.

(b) CRFI limits for +/- 33.5% of the pdf area from the mean (which would be equivalent to +/- 1 sd for a normal distribution) – CRFI limits were calculated to be 0.15 to 0.28 for this case (Figure 6). In contrast to the bare ice results, this has not skewed the CRFI range as the overall distribution is close to normal (Figure 3). Although this procedure gave reasonable results in this case, it is not recommended as its reliability depends on the shape of the initial distribution.

(c) CRFI limits for +/- 33.5% of the pdf area from the median – this produced the same CRFI range as for analyses based on the mean (Figure 3) as the distribution is close to normal.

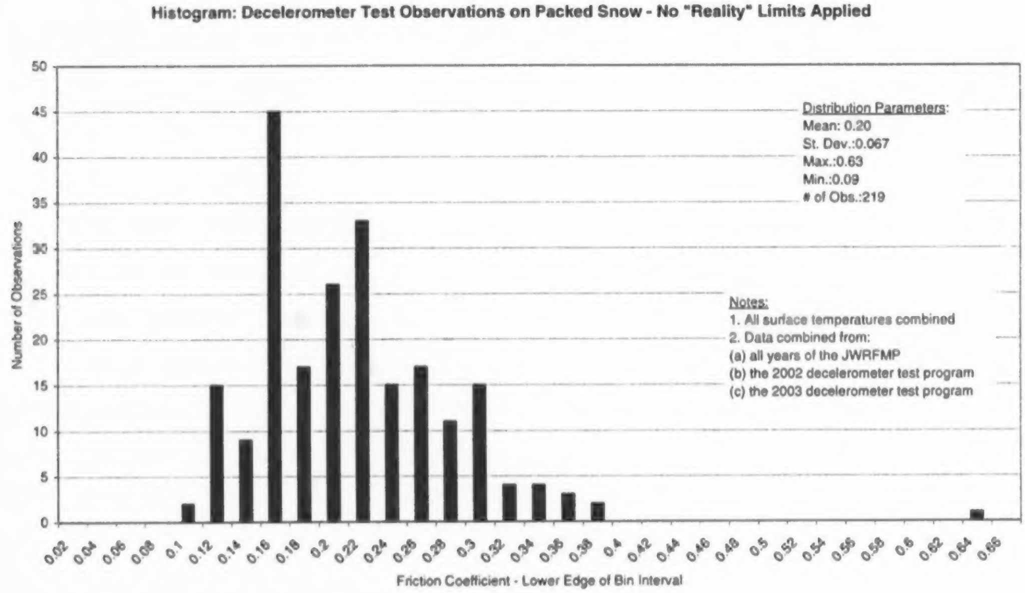
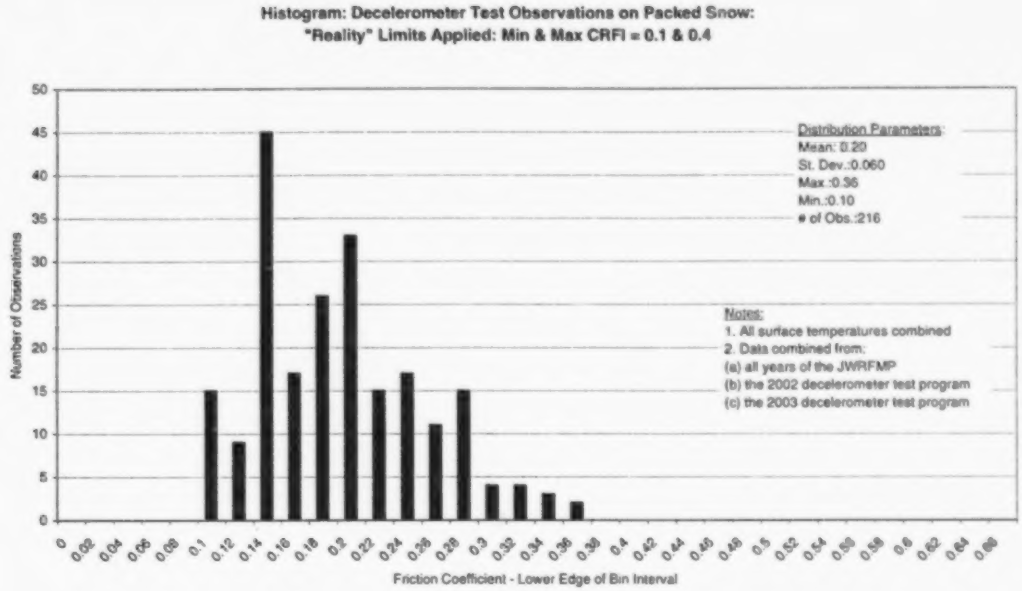


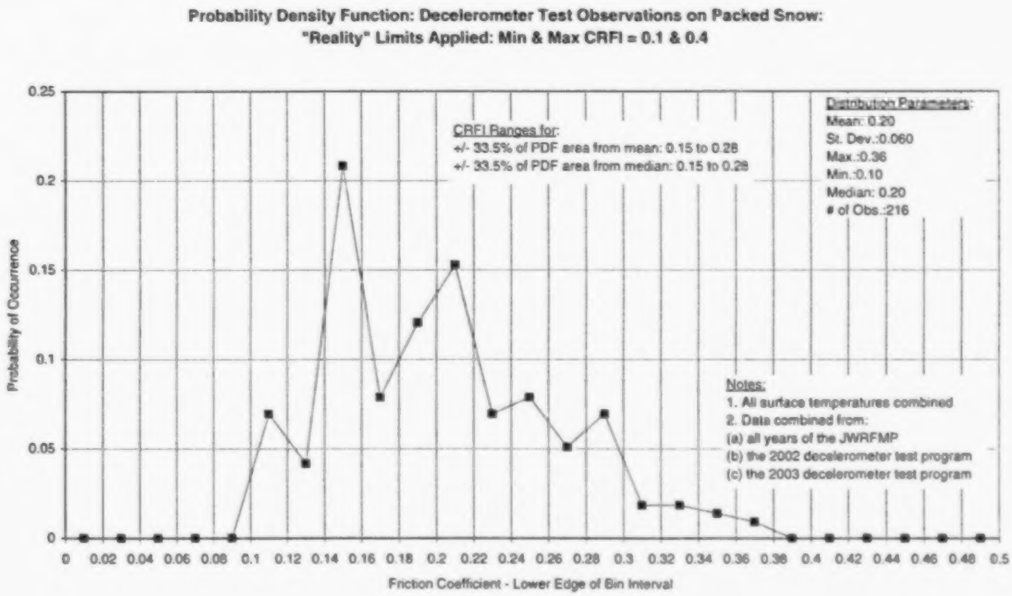
Figure 4


Histogram: Decelerometer Test Observations on Packed Snow:
"Reality" Limits Applied: Min & Max CRFI = 0.1 & 0.4

Distribution Parameters:
Mean: 0.20
St. Dev.:0.060
Max.:0.36
Min.:0.10
# of Obs.:216

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Figure 5


Probability Density Function: Decelerometer Test Observations on Packed Snow:
"Reality" Limits Applied: Min & Max CRFI = 0.1 & 0.4

CRFI Ranges for:
+/- 33.5% of PDF area from mean: 0.15 to 0.28
+/- 33.5% of PDF area from median: 0.15 to 0.28

Distribution Parameters:
Mean: 0.20
St. Dev.:0.060
Max.:0.36
Min.:0.10
Median: 0.20
# of Obs.:216

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Probability of Occurrence
0
0.05
0.1
0.15
0.2
0.25
Friction Coefficient - Lower Edge of Bin Interval
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
0.5

Figure 6

Results: Loose Snow on Pavement

As stated previously, these analyses were limited to snow depths between 3mm and 25 mm. These respective snow depths are:

(a) the limit at which the pavement ceases to have a strong effect on the CRFI (as described in our Jan. 14 memo), and;
(b) the limit at which Transport Canada considers decelerometer readings on snow to be unreliable.

This significantly limited the data quantity available. The full data set for decelerometer raedings on loose snow on pavement comprises 175 readings. The data set was reduced to 55 readings when the snow depth limit was applied. It should be noted that many of the rejected CRFIs wre eliminated because they did not have a snow depth associated with them as opposed to being outside of ther range defined by the above depth limits. The data set could be expanded if snow depth values were assigned to these CRFIs based on their surface description (eg, light snow on pavement, loose snow on pavement, drifting snow on pavement, etc) as every record in the JWRFMP database has a surface condition assigned to it.

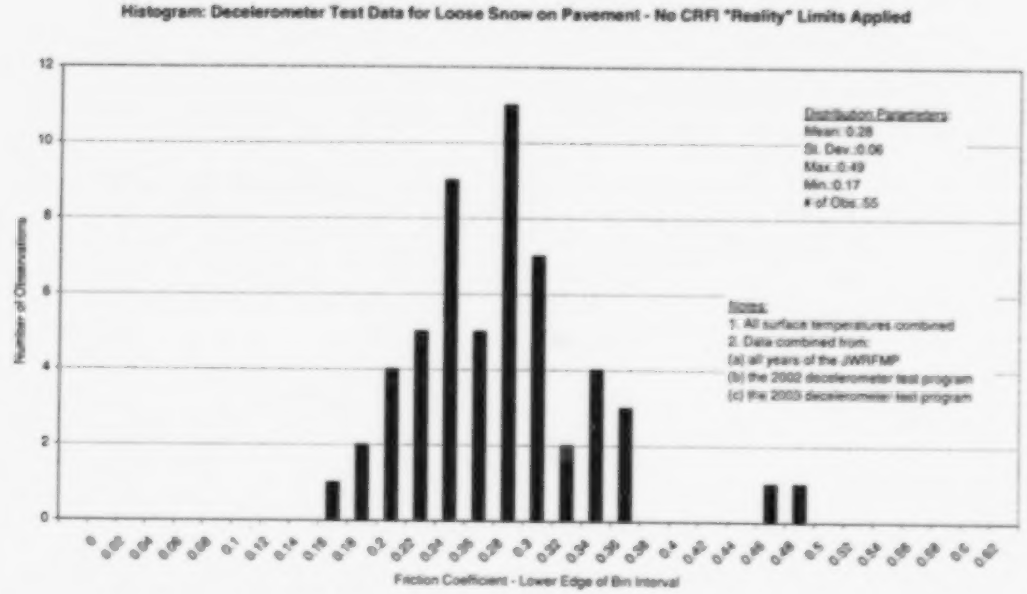
The data quantity was reduced further by a slight amount, to a total of 53 observations, when the CRFI "reality" limits of 0.1 and 0.4 (Table 1) were applied.

The results are plotted as follows:

(a) Figure 7 – histogram for the full data set (limited with respect to snow depth) but not limited with respect to the CRFI "reality limits" in Table 1
(b) Figure 8 – histogram for the data set with the application of both snow depth and CRFI "reality limits"
(c) Figure 9 – probability density function for the full data set with the application of both snow depth and CRFI "reality limits"

The same trends seen for the other surfaces are evident as:

(a) the removal of outliers had little effect on the overall distribution or its parameters (e.g., mean, standard deviation) as only 2 of 55 observations were removed from the distribution. This had the desired intent of not changing the distribution. However, the maximum CRFI was reduced significantly by removing the outliers, which again shows that the intended result was achieved.
(b) CRFI limits for +/- 33.5% of the pdf area from the mean (which would be equivalent to +/- 1 sd for a normal distribution) – CRFI limits were calculated to be 0.23 to 0.31 for this case (Figure 9). In contrast to the bare ice results, this has not skewed the CRFI range as the overall distribution is close to normal (Figure 8). Although this procedure gave reasonable results in this case, it is not recommended as its reliability depends on the shape of the initial distribution.
(c) CRFI limits for +/- 33.5% of the pdf area from the median – this produced the same CRFI range as for analyses based on the mean (Figure 9) as the distribution is close to normal.

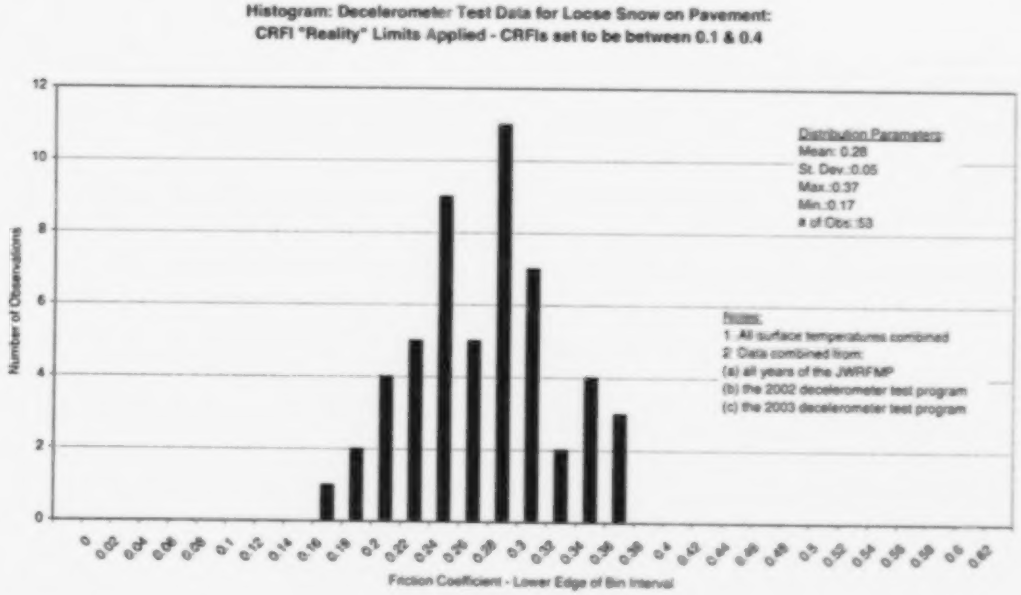


Histogram: Decelerometer Test Data for Loose Snow on Pavement - No CRFI "Reality" Limits Applied

Distribution Parameters:
Mean: 0.28
St. Dev.:0.06
Max.:0.49
Min.:0.17
# of Obs.:55

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Figure 7



Histogram: Decelerometer Test Data for Loose Snow on Pavement:
CRFI "Reality" Limits Applied - CRFIs set to be between 0.1 & 0.4

Distribution Parameters:
Mean: 0.28
St. Dev.:0.05
Max.:0.37
Min.:0.17
# of Obs.:53

Notes:
1. All surface temperatures combined
2. Data combined from:
(a) all years of the JWRFMP
(b) the 2002 decelerometer test program
(c) the 2003 decelerometer test program

Figure 8

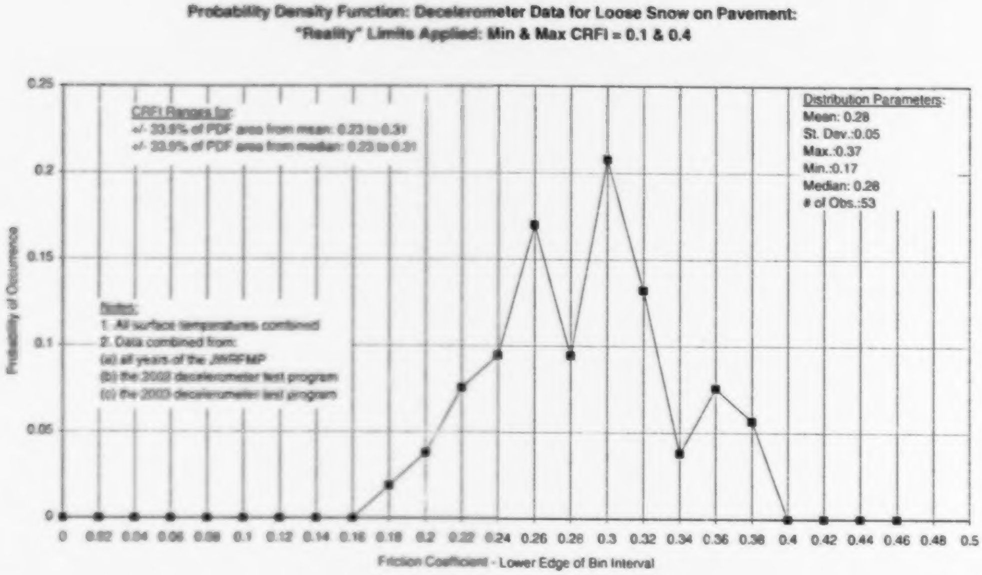


Figure 9

Conclusions and Recommendations

The combined data set provides sufficient data to undertake statistical analyses with confidence.

It is recommended that:

(a) the combined data set be used for all analyses for decelerometers
(b) the reality limits in Table 1 be applied
(c) CRFI limits be calculated based on the median of the population such that they encompass +/- 33.5% of the area under the pdf

References

[1] Comfort, G., 2003, Effect of Surface Conditions on the Friction Coefficients Measured on Winter Surfaces, BMT FTL report 5416, now being published by Transport Canada.

[2] Comfort, G., and Ryan, M., 2002, Effect of Vehicle Parameters on the Friction Coefficients Measured by Decelerometers on Winter Surfaces, Transport Canada report TP13980E.

[3] Comfort, G., and Verbit, S., 2003, Decelerometer Tests: CRFI Quality Assurance Tests and the Effect of the Vehicle's ABS System, Transport Canada report, TP# to come.

APPENDIX C.4

CRFI UPDATES FOR THE AIP: RANGE OF VALUES TO BE INCLUDED

June 22, 2004
BMT FTL File: 5699

To: Angelo Boccanfuso, Transportation Development Centre
J. Martin, Transport Canada
P. Carson, Transport Canada
J. Croll, National Research Council

From: George Comfort BMT Fleet Technology Ltd.

Re: CRFI Updates for the AIP: Range of Values to be Included

This memo is sent to follow up meetings (with Jim Martin), and the question raised by Jim Martin regarding whether or not the present Landing Distance tables already account for some uncertainty in the CRFI. I only sent this to a restricted distribution to give you a chance to review this first and to provide input.

The question poised by Jim on uncertainty is a valid one. Uncertainty however applies to all the calculations used to determine aircraft landing distances. How much uncertainty is accounted for in the updated CRFI/Landing distance tables is difficult to answer and is probably best left to NRC to do so, since they know what field data points were used and which ones were not and what assumptions were made.

Nevertheless, we reviewed NRC report LTR-FR-183 (by Croll et al, 2002) as suggested by Jim. It shows that the relationship used to establish the $\mu_{braking}$ – CRFI relationship is a lower-bound (hence, conservative) fit to the data (Figure 1).

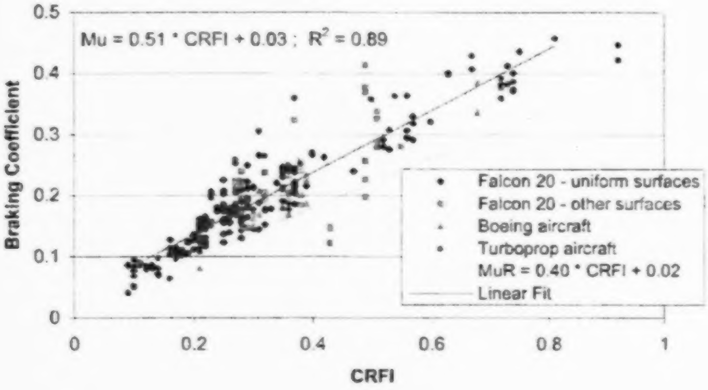


Figure 1

There is no doubt that, as Jim Martin says, each data point in Figure 1 has an "ellipse of uncertainty" associated with it that is defined by:

(a) y-direction: uncertainty in the $\mu_{braking}$ determination and aircraft performance data.
(b) x-direction: uncertainty in defining the CRFI for the surface tested, which includes the variability of that surface, and the errors associated with making the CRFI measurement.

By using the lower-bound fit in Figure 1, the analyses not only account for some uncertainty in the data collected, but also, they provide a degree of confidence in the final product (i.e., the CRFI/landing distance tables). As stated in the NRC report, the use of the lower-bound line (in Figure 1) provided a confidence level of over 95% for the provided data.

The appropriate answer to Jim's question depends on the intended end use of the CRFI/surface type table. The NRC report indicates that the CRFI/Landing distance table applies to the "Reported CRFI". (This is stated explicitly for some tables while for others, it is implied). This suggests to us that the CRFI/Landing distance table is intended to be **valid only** when a runway friction value is measured by an airport operator which is using decelerometers.

We expect that the CRFI/surface type table and the CRFI/Landing distance table have completely different uses, and that it was not intended, nor should it be done, that data from one table are used to obtain information from the other table. Please correct us if we are wrong. Perhaps you can provide us with some information on how the tables are currently being used?

The CRFI/surface type table in our view should not be used to select a friction value to apply to the CRFI/Landing distance table. The CRFI/surface type table should be used for general information. The table can provide data on the how much the runway friction value **can vary** on various contaminated runway surface conditions. The table would perhaps be of some benefit to pilots which operate aircraft into airports that **do not measure friction.** In such cases the pilot would only be given information on what is on the runway (i.e., a surface condition description) and he would then have to interpret this information into braking performance of his aircraft. The CRFI/Surface type table could be used to provide him with some information on the possible friction levels he may encounter. Unfortunately, which friction value to use would be left to the discretion of the pilot. The way around this would be to require all airports to measure friction using decelerometers.

If this understanding is correct, then the updated "CRFI value vs Surface Type" table in the AIP can be developed separately from the $\mu_{braking}$ – CRFI relationship, and hence the Landing Distance Tables that have been established from them.

The development proposed for the CRFI/surface type table is generally similar to that which was done for the CRFI/Landing distance table.

a) With respect to the CRFI/Landing distance table, the concern at that time was that the existing table could not be supported because it was unclear: (i) what data were used in determining the landing distances ; (ii) how the landing distances were derived, and; (iii) there was no technical documentation on this matter. In order to provide some technical credibility to the CRFI/Landing distance table, data from the field tests conducted as part of the JWRFMP was used. Assumptions were made on what data points to use, landing distances were recalculated, and a decision was made to select a lower bound limit to give roughly, the 95% confidence level [NRC report LTR-FR-183].

b) The concern with the current CRFI/Surface type table is the same as that which existed with the previous Landing Distance table, as the basis for the existing CRFI/Surface type table is unclear. A similar approach is being proposed for the CRFI/Surface type table as was taken for the Landing Distance table. The data to be used for surfaces and the CRFI will be taken from the source used for the CRFI/Landing distance table. Various distributions of measured friction values vis a vis surface type would be developed which would enable you to select a CRFI range depending upon what confidence level you wish to put on the data. We would give you a recommendation on the range we should suggest, but, the final decision, of course, would be up to you.

We trust that the above provides you with the information you requested, and that you are in agreement. As we are anxious to re-start, and thus complete, the project, would you please contact us as soon as possible with any further questions or comments that you may have.

Thank you

G. Comfort

References

[1] Croll, J., Bastian, M., Martin, J., and Carson, P, 2002, Evaluation of Aircraft Braking Performance on Winter Contaminated Runways and Prediction of Aircraft landing Distance Using the Canadian Runway Friction Index, NRC Report LTR-FR-183, also Transport Canada Report TP 13943E.

APPENDIX C.5

CRFI UPDATES FOR THE AIP: COMPARISON OF SFT DATA

March 31, 2004
BMT FTL File: 5699

To: Alice Krol, Transport Canada
cc: Angelo Boccanfuso, Transportation Development Centre

From: George Comfort BMT Fleet Technology Ltd.

Re: CRFI Updates for the AIP: Comparison of SFT Data

To follow up our March 25 report, and your email, we searched the JWRFMP database for: (a) the TC SFT'79 (Configuration 3); (b) the SFT 900 (Configuration 3), and; (c) the TC SFT Turbo (Configuration 1). Searches were done for

(a) Surfaces – bare ice & bare packed snow
(b) Speeds – all speeds
(c) Sites & Years – all included
(d) Track section – average friction coefficient for whole track outputted

Results: Bare Packed Snow

No cases were obtained where all three, or even two, of the above devices were run together during the same test. Thus, no matched pair data were obtained.

Consequently, comparisons are not possible for bare packed snow.

Results: Bare Ice

Only four tests were done in which all three, or even two, of the above devices were tested together. These data are summarized in Table 1. These four tests were all done at North Bay in 1999 during test 99.27.1A, which was described as a "Special Comparative Test of Transport Canada SFT's".

Table 1 SFT Comparison for Bare Ice

TC SFT'79		SFT 900		TC SFT Turbo	
Speed, km/hr	Avg mu	Speed, km/hr	Avg mu	Speed, km/hr	Avg mu
41	0.11	42	0.16	54	0.29
41	0.12	42	0.16	50	0.28
62	0.15	67	0.19	62	0.29
65	0.11	66	0.18	65	0.30

The average friction coefficients differ significantly among the three devices, especially for the TC SFT Turbo.

Do you have any comments regarding these results?

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